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Operation UPSHOT-KNOTHOLE

NEVADA PROVING GROUNDS

March - June 1953

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Project 3.30

AIR BLAST GAGE STUDIES

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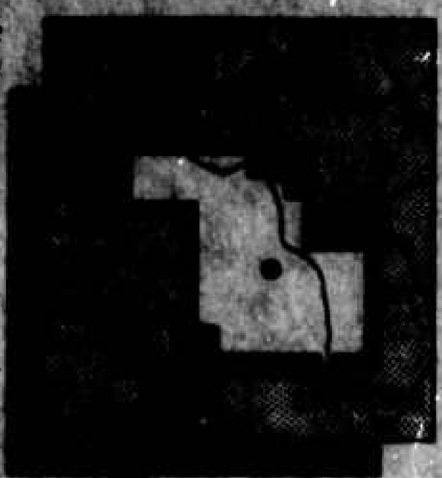

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OPERATION UPSHOT-KNOTHOLE

Project 3.30

AIR BLAST GAGE STUDIES

REPORT TO THE TEST DIRECTOR

by

Charles N. Kingery
and
Marvin F. Clarke

June 1954

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ABSTRACT

The purpose of Project 3.30 of Operation Upshot-Knothole was to develop and proof-test self-recording gages for the measurement of pressure-time and peak pressure in connection with air blast waves from nuclear explosions.

To accomplish this purpose, prototypes were manufactured for three types of gages in quantities of 10 to 30. They were employed in numerous ways on several shots to determine their characteristics, limitations and capabilities. A nylon and carbon paper initiation device was used on the pressure-time gages to start the recording disc at a finite time after the detonation of the device.

The pressure-time gages were accurate to ± 10 percent and recorded wave shapes very similar to those obtained by more expensive electronic instrumentation. The peak pressure gages were accurate to ± 10 percent and no initiation device was needed.

The components of the gages tested form a basis for other gages to measure flow phenomena, underwater pressures, ground shock, acceleration and temperature phenomena. It is recommended that the development of a series of self-recording gages for the measurement of various phenomena associated with the detonation of atomic devices be vigorously pursued.

It is concluded that gages of the type tested can give useful data, on tests requiring greater coverage and longer blast lines, with sufficient accuracy and for less expenditure in money, man-power, and time, than is possible with other types of instrumentation.

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FOREWORD

This report is one of the reports presenting the results of the 78 projects participating in the Military Effects Tests Program of Operation UPSHOT-KNOTHOLE, which included 11 test detonations. For readers interested in other pertinent test information, reference is made to WT-782, Summary Report of the Technical Director, Military Effects Program. This summary report includes the following information of possible general interest.

a. An over-all description of each detonation, including yield, height of burst, ground zero location, time of detonation, ambient atmospheric conditions at detonation, etc., for the 11 shots.

b. Compilation and correlation of all project results on the basic measurements of blast and shock, thermal radiation, and nuclear radiation.

c. Compilation and correlation of the various project results on weapons effects.

d. A summary of each project, including objectives and results.

e. A complete listing of all reports covering the Military Effects Tests Program.

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PREFACE

This report has been written to disseminate the information contained in order that other organizations might be encouraged to build better, cheaper, and more accurate gages for the measurement of natural phenomena resulting from the detonation of nuclear devices. The authors feel that the information contained in this report offers several possibilities which should be of interest to those who are interested in gage development along the line of simple self-contained recording gages.

The authors wish to acknowledge the aid they received from Dr. Curtis W. Lampson for the conception of a simple self-recording gage, from Dr. E. E. Minor for technical assistance in developing a satisfactory gage, from Fred Harris for many basic ideas used in these gages, from Gerald Ginty for many of the initiation devices and from many others who aided and assisted in the development, design, procurement, and field testing of the components and gages.

The authors wish to acknowledge especially the aid and assistance rendered by 2nd Lieutenant John B. Critchlow in the field testing of these gages and the aid rendered by A/2c Richard C. Wagner whose mechanical skill aided in the design and fabrication of prototypes.

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CHAPTER I

INTRODUCTION

1.1 OBJECTIVES

The objective of Project 3.30 was to develop and proof-test self-contained recording gages for the measurement of pressure-time phenomena in connection with air blast from nuclear detonations.

The secondary mission of this project was to develop and proof-test a peak-pressure recording gage.

The significance of this project lies in the possible savings in money, time, and effort in the determination of the military effects of atomic weapons if a suitable self-contained gage could be developed. Such a gage would eliminate the costly instrument shelters, cables, cable trenches, and recording and play-back equipment that are necessary with electronic measuring equipment now used. Low cost and simplicity of installation make it possible to use these gages on a large scale.

The cost of these gages per channel of recorded pressure-time data should be less than 20 percent as much as the cost of electronic measurements.

1.2 HISTORY

The use of pressure gages which employ the displacement of a diaphragm to sense the pressure differential across the diaphragm has been common in industry and science for many years. The use of such diaphragm to sense the pressure of shock waves has been accomplished many times. This type of application has been somewhat limited in scope because the frequency of the natural vibrations of diaphragms has made them inconvenient to use unless the displacement could be amplified and measured electronically.

In 1952, the Naval Medical Research Institute (NMRI) developed a small pressure-time recording gage which used a stylus attached directly to a diaphragm to record the displacement caused by a shock wave. Their sensing element consisted of two diaphragms, soldered together around the edges, and evacuated. The pressure on the outside of the element compressed the diaphragms and the stylus scratched a record of the diaphragm displacement on a rotating smoked drum or disc to give a pressure-time curve. The recording apparatus, element and starting mechanism of this gage were shock mounted by suspending them inside a box from springs or rubber bands. Pressure was admitted to the box through a small opening. Edgerton Germeshausen and Grier time signals were used to start the recorders.

The NMRI used the gages inside their animal shelters to determine the pressure-time phenomena to which their animals were subjected. They were successful in obtaining records which agreed within $\pm$ 10 percent of the pressure-times obtained by electronic measurements, and which also exhibited the characteristic wave shapes.

Personnel from the Ballistic Research Laboratories (BRL) redesigned and adapted the gage to the measurement of free air and ground surface pressure-time and peak-pressure.

1.3 DEVELOPMENT

The development of self-contained gages for the measurement of pressures and other phenomena in connection with the detonation of nuclear devices is a continuing project at BRL.

1.3.1 Pressure Sensing Elements

The first requirement for a successful gage was to find a sensing element which would respond to a step increase in pressure. Many tests were made on different types of elements using the two shock tubes at BRL to simulate the pressure-time phenomena of air shock waves obtained by nuclear detonations. It was clearly demonstrated that for step increases of 1 to 2 msec duration, pressure capsules could be made which would respond to a shock pressure exactly as they did to a static pressure. This meant that these capsules could be statically calibrated and the static curve could be used to read dynamic shock pressures.

Basing the design on the information obtained from the shock tube studies of pressure-time response of pressure capsules when subjected to dynamic shock waves, a series of pressure capsules were obtained with pressure ranges of 0, to 5, 10, 15, 25, 50, 100, and 150 psi maximum pressures. The fill-in time for these pressure elements was reduced by using a nested type of diaphragm construction which left only one thirty-second of an inch between the two diaphragms. The response to shock waves was further increased by reducing the mass of the diaphragm and stylus to a minimum consistent with the rigidity and elasticity necessary to insure good recording. NiSpan C was chosen as the material for the diaphragms because of its low coefficient of thermal expansion and internal hysteresis. This material had a repeatable displacement of the diaphragm per unit pressure over any normal temperature span encountered in field work. The diameter of the pressure sensing element was reduced to increase its natural frequency of vibration and to minimize the volume and, hence, the fill-in time. The thicknesses of the diaphragms chosen for each pressure range were selected to reduce the displacement to a minimum amount consistent with the resolution of the reading equipment and the accuracy desired from the measurements. The construction of these elements was done by the use of dies and the connections were silver-soldered and then treated by a cold precipitation method to reduce strains and fatigue in the metal.

The elements obtained were linear to ± 1/2 percent and had a hysteresis of less than ± 1/2 percent. They were interchangeable in the gages, thus any gage could be used for any pressure range for which the elements were available.

The natural frequencies of the elements when shock excited varied with the thickness of the diaphragms. For the pressure ranges between 5 psi and 150 psi, the natural frequencies, undamped, were between approximately 1400 and 1800 cps. When used in the peak-pressure gages, the pressure sensing elements were over-damped because the gage read maximum deflection only and it was desired that the record have no over-shoot. When the pressure-time gage was used with these elements, they were also damped by placing steel wool in the pressure inlet. This increased the rise time from 1/2 msec to about 3 msec but made the record much more easily read and improved the accuracy of the readings. The slow recording speed of these gages made the time resolution of the system about the same as the rise time of the element.

The maximum deflection of the diaphragms for any maximum pressure range varied from 0.030 to 0.050 in. It is possible to design similar elements for pressure ranges as low as a few inches of water pressure (i.e.,0.1 psi) and as high as 600 psi and probably still higher.

1.3.2 Recording

Considerable work was done to find a good recording system which would reduce the friction between the stylus and the recording blank and still be reliable and accurate. The stylus was finally made of the point of a microgroove phonograph needle. This needle had a 0.001 in. diameter hemispherical point. It was fastened to a piece of steel shim stock, which was 0.125 in. wide, 0.500 in. long and 0.004 in. thick. This was cold soldered to the center of one diaphragm of the capsule opposite the pressure inlet. It was rigid along its longitudinal axis to take the thrust of the pressure capsule and to transmit the displacement of the diaphragm to a scratch under the needle point. It was rigid in the transverse axis to resist the drag of the recording blank beneath the needle point. It was elastic along the vertical axis to maintain a constant pressure of the needle point on the recording blank.

Many tests were required to determine a suitable recording medium. The smoked drums used by NMRI were satisfactory but were subject to damage by handling and were difficult to read and to enlarge.

Metal discs of steel, brass, copper, and aluminum were used with some success. Lubricated discs were also tried. Smoked surfaces, dyed surfaces, waxed surfaces, and plated surfaces were tried with varying success. The final choice was a glass recording disc coated with a thin layer of machinists blue lay-out fluid and then coated with a thin layer of 20 centistoke silicone oil to lubricate the needle point. This combination gave scratch marks of approximately .0005 in. wide with very sharp edges which permitted measurements from one scratch to another to an accuracy of + 0.0002 in. The glass was very smooth and the needle-point was hemispherical and the combination was bathed in oil so there was little wear of the needle-point even after several hundred revolutions of the record turn-table. Ordinary steel phonograph needles, which have a 0.003 in. diameter hemispherical point, were also used on some elements and give records essentially as good as the microgroove needles.

During various periods of experimentation with these gages, different turn-table speeds were used for recording pressure-time phenomena. Speeds as high as 14 in/sec past the needle point were used when checking the rise time of the pressure sensing elements. This speed permitted time resolutions of the order of 14 microseconds to be obtained with the record reading system used. The "A" gages used on this series of shots had a turn-table speed of approximately 0.11 in/sec which permitted a time resolution of the order of 0.01 sec to be obtained. The clock-initiated gages which were used on the last four shots had turn-table speeds of the order of 0.8 in/sec which permitted time resolutions of the order of 0.001 sec.

1.3.3 Preliminary Tests

Some work was done at Aberdeen Proving Ground with the prototype gages to test their applicability to small charge measurements. Some pressure-time curves were obtained from the shock wave originating from the detonation of a 1000 lb charge of TNT in the 10 psi pressure region, and some peak-pressure measurements were obtained in the region of 40 psi pressures. Attempts to use these gages with 1 lb charges and 8 lb charges of TNT were unsatisfactory because of the peaked nature of the shock wave from small charges and the extremely short durations involved. The attempt did indicate that further development might provide an easy means of measuring peak pressures from small charges but that special calibrations would be necessary. It is doubtful that pressure-time data from small charges can be measured because of the inherent limitations of the diaphragms if displacements of several thousandths of an inch are required to record the pressure accurately.

1.3.4 Production Models

Using the information obtained in the preliminary investigations at BRL, a set of specifications was drawn up for a peak-pressure gage and a pressure-time recording gage. Project 3.28.1 requested 15 of each of these two types of gages as back-up measurements for the electronic measurements they intended to make on UPSHOT-KNOTHOLE. Project 3.21 also asked for a similar number.

The pressure-time gages ordered were the clock-initiated gages. These gages employed a 24 hour clock to start the gage a few minutes prior to shot time, let them run 15 minutes, and then turned them off.

The turn-table speed and the diameter of the trace on the record were so chosen that the full pressure-time phenomena of a nominal nuclear device would be recorded on one turn of the turn-table and the needle would return to the zero pressure position before the record was retraced again. Thus the base line would be retraced every 12 sec while the gage was running, but the pressure-time curve would not be obliterated by subsequent scratches of the needle.

These gages used a 7 1/2 volt battery for power for the record drive. The record speed was controlled by a vibrating reed which acted as a governor on the drive motor. The gage is shown in Fig. 1.1.

The peak-pressure recording gages may be seen in Fig. 1.2. These gages used the same pressure sensing elements and stylus as the pressure-time recording gages but used a fixed recording blank. The record blank was a small rectangular glass plate coated with machinist blue lay-out fluid painted on with a small camels' hair brush and coated with a film of 20 centistoke silicone oil to lubricate the needle. A slide way was provided for mounting the glass record blank. When inserted in the record holder, the glass blank was slid in a direction at right angles to the movement the stylus would make when deflected by a pressure in the capsule. This mark on the glass was the zero reference from which a positive deflection of the needle caused by pressure in the capsule could be measured.

Both this gage and the pressure-time recording gage were provided with 3 in. tapered pipe threads on the cases so they could be mounted on pipe mounts for free air measurements. They were also provided with baffle plates to permit stream-lining for overpressure measurements in free air. When used in the wall of a building or flush with the surface of the ground this baffle was not used.

The gage cases were provided with sintered metal plugs which permitted a slow leakage of air into or out of the gage case. The pressure sensing element, in all cases, measured the differential pressure between the pressure admitted to the sensing element from outside and the air pressure trapped inside the gage case. The sintered plug offered a slow leak which permitted the pressure inside and outside of the case to equalize over a long time period.

These pressure-time gages cost approximately 142 dollars each plus 17 dollars each for the pressure sensing elements. The cost of re-orders of the pressure sensing elements for which dies now exist will probably be less.

The peak pressure recording gages cost 38 dollars each plus the cost of the pressure sensing elements noted above. The gages could be reduced to 1/4th of their present size or less and should be less expensive to produce.

Two types of pressure-time recording gages were tested during UPSHOT-KNOTHOLE. One was the clock gage which started recording at the preset time and is noted in tables as the "C" gage. The other type known as the "A" gage is started by a thermal initiator. These gages were designed and constructed at the Aberdeen Proving Ground. The record drive motors in these gages were clockwork timers of the type used in the M-500 artillery fuses. This gage may be seen in Fig. 1.3.

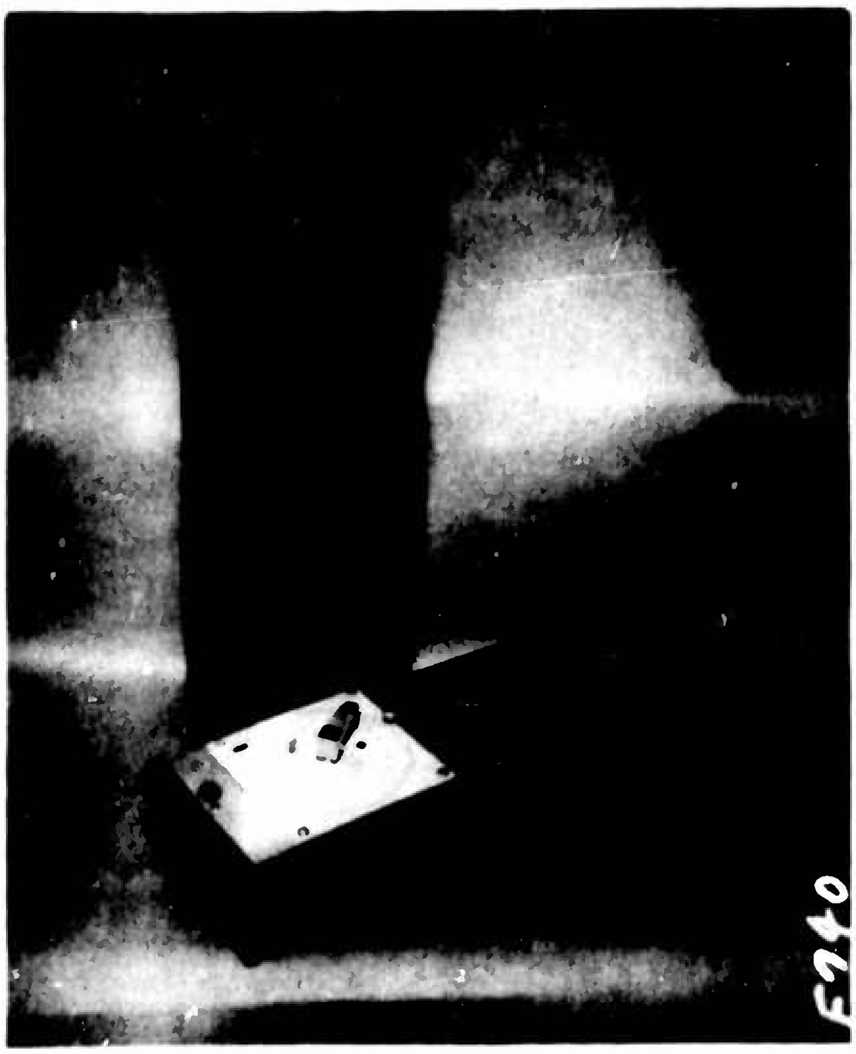

Fig. 1.1 A Clock Initiated, Pressure-Time Recording Gage

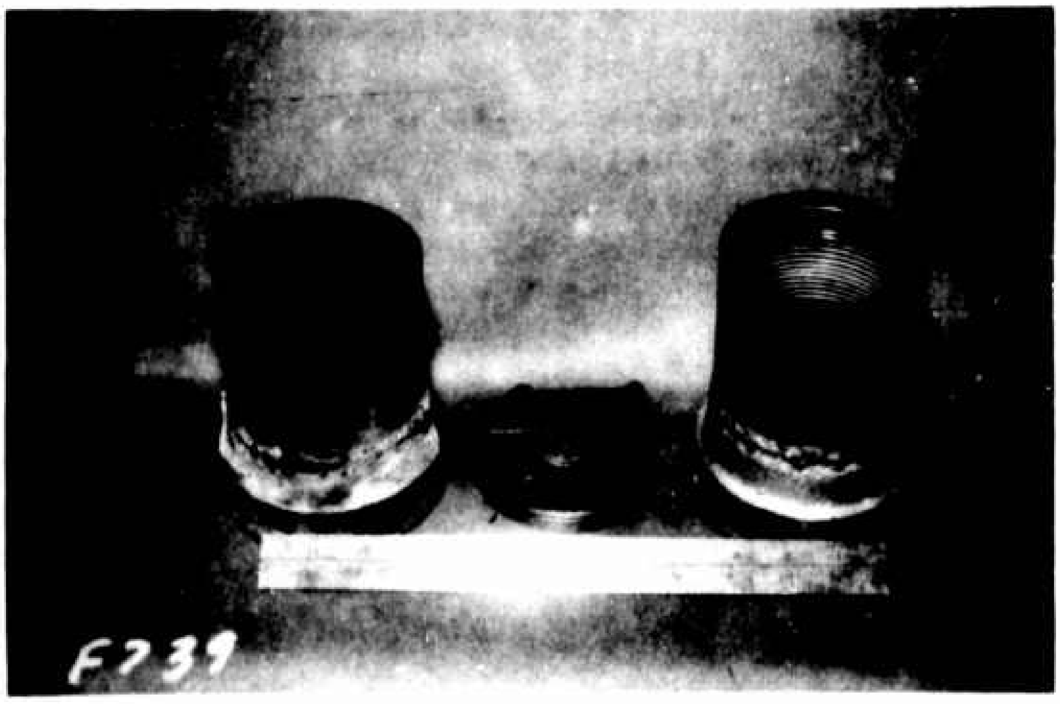

Fig. 1.2 A Peak Pressure Recording Gage

1.3.5 Thermal Initiators

Recognizing the inherent problems of a gage which started recording at a pre-set time and stopped after a limited running time, an effort was made to find a simple means of initiating the recording system of a self-contained pressure-time recorder from the flash of the detonation. All drive motors require some time to start and reach a constant running speed, and since the timing of the pressure phenomena depended on the constant speed of the record blank, it was desirable to start the recorder either before the detonation of the bomb or as soon thereafter as possible. The obvious solution to this problem was a phototube initiator, but this solution involved batteries, tubes, wires, and relays. A simple method of accomplishing this was developed but, at the same time, an effort was made to find other means of initiation. This line of investigation was based on the possibility of using the high thermal radiation of a nuclear detonation to burn a fusible link to start the recorders.

Some work was done on GREENHOUSE using black nylon ribbon to trigger camera hatch covers when the ribbon was burned by the thermal radiation. This system had approximately 2.5 sec lag in triggering but indicated certain possibilities. The investigation of fusible links was carried out by means of a burning glass, masks, and the sun, which permitted various heating levels to be obtained. It was finally determined that nylon thread offered both the necessary strength and the small size and low melting point necessary to reduce the triggering time to an acceptable figure. It was also found, if the nylon was shaded by a piece of carbon paper, the increased area and absorption rate reduced the triggering time still more.

The nylon and carbon paper system was used on an "A" type time recording gage for initiation of the record drive mechanism by the thermal radiation of the nuclear detonation. This gage and thermal initiator is shown in Fig. 1.3. Four of these were built and were used on Shot 1 to test the nylon and carbon paper initiation system at various distances. The Shot 1 results demonstrated the feasibility of this type of gage, and 10 more were constructed at BRL for experimental purposes on UPSHOT-KNOTHOLE.

Further experimentation was attempted in connection with this series of tests to determine the limitations of this type of initiation. By using a lens to focus the thermal radiation on the Nylon, this system has been demonstrated to be usable up to 7 1/2 miles from a nominal bomb. The lag of the burning of the nylon is small enough that it has been used successfully within 1200 ft of a nuclear detonation and the recorder started in time to record the pressure-time phenomena for the gages at that station.

Realizing that a gage that had to have a direct line of sight to the point of detonation of the bomb had serious limitations in its use in structures or behind objects, an effort was made to find a remote triggering device which could be attached to these mechanical gages without modifying the gage.

The result of this was a device which is shown in Fig. 1.4. It was designed to use a very small resistor which replaced the nylon

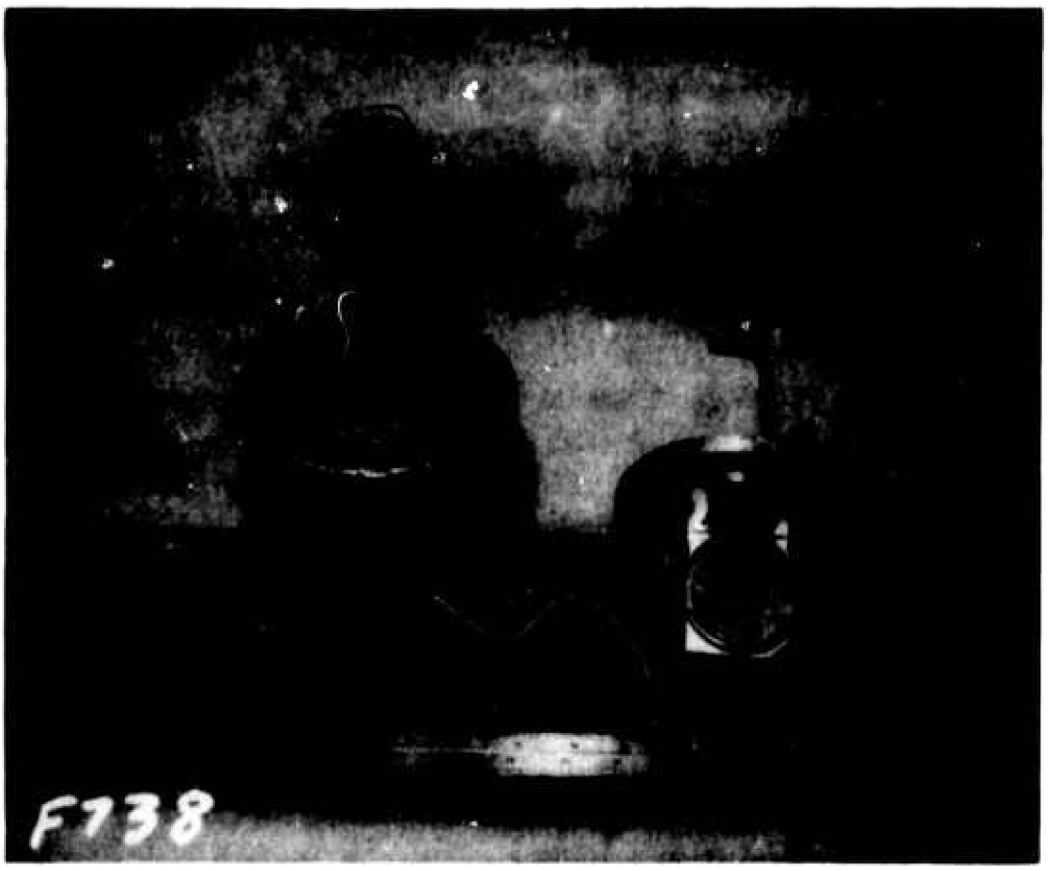

Fig. 1.3 Nylon Thread and Carbon Paper Initiator on a Spring Wound Pressure-Time Recording Gage

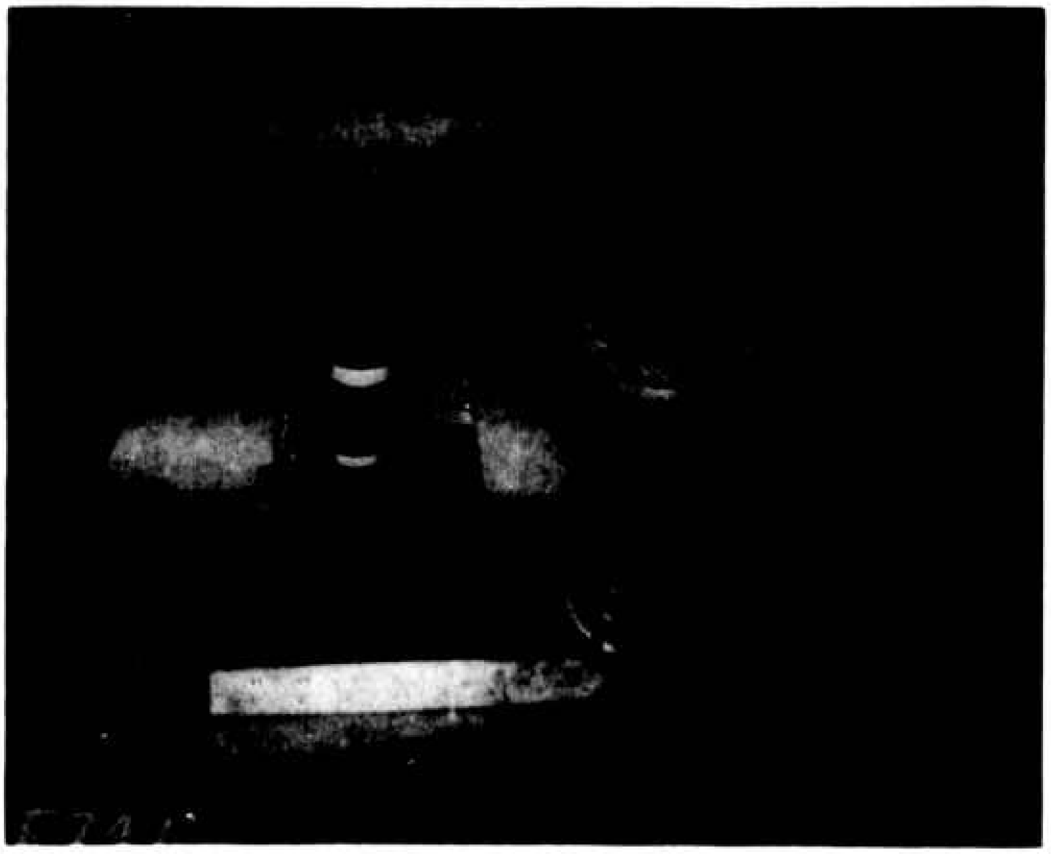

Fig. 1.4 A Phototube and Fusible Link Initiator

thread. This resistor was burned in two, as a fusible link, by a current from a battery. The device used a phototube to detect the detonation and a cold cathode thyratron to pass enough current to burn the fusible link. A light shield and filter were used to keep the phototube from triggering on spurious signals. The device was small, battery operated, and self-contained, and required only a twisted pair to connect it to the pressure-time gage. It operated satisfactorily at distances up to 7 1/2 miles from a 30 KT nuclear device. The time delay of the fusible link is less than a second but the lower limit has not been determined.

1.3.6 Pressure-Time Measurements Under Water

The possibility of using these gages to measure the pressure-time phenomena on the bottom of shallow bodies of water was of interest to many people. Two gages were modified to extend the triggering device using the nylon thread and carbon paper several feet above the gage. This device can be seen protruding from a barrel in Fig. 1.5. The gages were then placed at the bottom of a barrel of water which was sunk into the ground. The gages worked very well and pressure-time records were obtained. A peak-pressure gage was also used on this test and on a later test. These required no modification but the element was carefully filled with water before the gage was submerged to insure the elimination of any air bubbles in the element.

1.3.7 "q" Gage

The problem of measuring the "q" or "drag pressure" of a shock wave was one that could be accomplished by a mechanical pressure-time gage of this type. One gage was adapted for this type of measurement by adding a pitot tube which put a stagnation pressure inside the element and a static pressure opening was cut through the baffle which put the static pressure inside the gage case on the other side of the pressure sensing diaphragm. This gage may be seen in Fig. 1.6. Thus, this gage read the differential pressure between a pitot tube and a static pressure opening. The fill-in time in the gage case was reduced by filling as much of the volume of the case with solid matter as possible and by making the static pressure hole large. Only one such gage was modified in the field and when used on Shot 11 was blown from its mounts and lost. Therefore, no record was obtained. Development work has been carried on and a workable self-contained "q" gage was used during the CASTLE operation.

1.3.8 Acceleration Measurements

The possibility of making ground acceleration measurements and using this type of scratch recording was also investigated. Acceleration elements have been tested which are linear to + 5 percent or less and have a natural undamped frequency of 54 cps. These can be recorded on the scratch recorder. Two elements were used on one of the nylon initiated pressure-time recording gages. This means that the record blank for this gage had three traces. It recorded pressure-time, vertical acceleration vs time, and transverse acceleration vs time. This gage was used on several shots and gave good results. The acceleration elements were crude but indicate that a good gage of this type is feasible with more development work.

Fig. 1.5 Snorkel Tube to Extend the Nylon Initiator Above the Water Surface

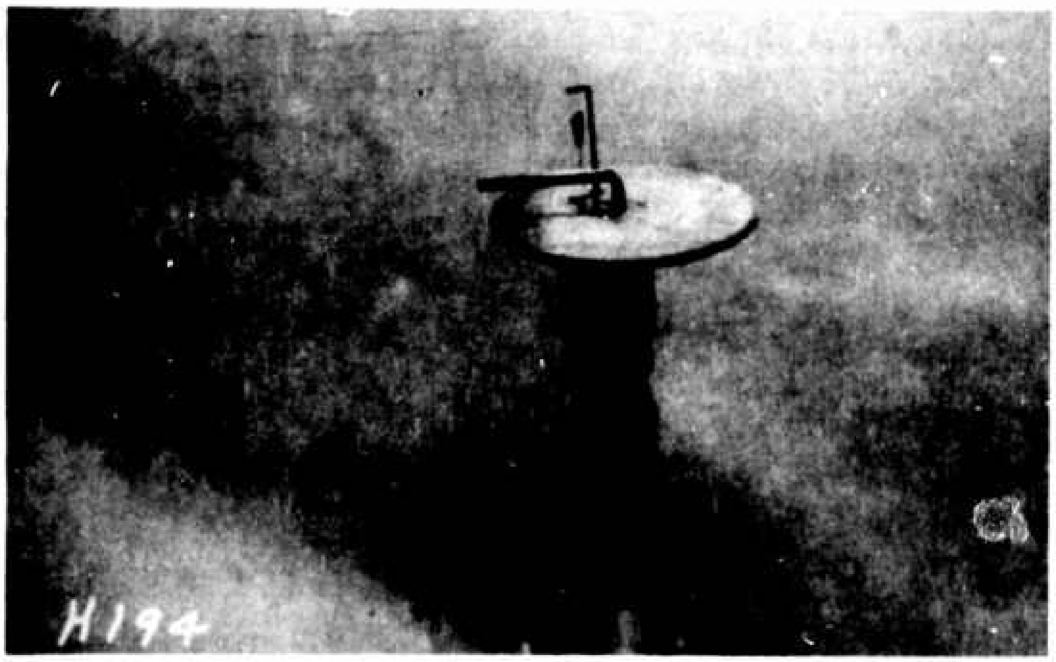

Fig. 1.6 A Pressure-Time Recorder Modified to Measure "q"

CHAPTER 2

INSTRUMENTATION

2.1 SHOT 1

The purpose of the test on Shot 1 was to determine the feasibility of using a nylon thread and carbon paper for thermal initiation. The nylon thread was to be melted by the thermal radiation of a nuclear detonation, thus starting a pressure-time gage recorder prior to the arrival of the air shock wave at the gage. Only four prototype "A" gages were used on this test.

The gages were placed at ground level near the pressure gages used by Sandia Corporation.[1] The four distances are shown in the Gage Layout in Fig. 2.1. They were installed by digging a shallow hole in the sand and burying the gage with the flat face flush with the surface of the ground. The Nylon thread was wound in a block-and-tackle fashion between a fixed arm and the ring in the trigger rod to the record drive mechanism. Carbon paper was glued to the Nylon thread to increase the area exposed to radiation. A thread and carbon paper assembly may be seen in Fig. 1.3.

2.2 SHOT 7

The purpose of the test on Shot 7 was to try these gages for comparative measurements with the electronic instrumentation used by Sandia Corporation,[1] to check the asymmetry of the blast wave, and to further test the nylon and carbon paper thermal initiation device.

The gages were installed as shown in the gage lay-out for Shot 7 in Fig. 2.2. They were mounted in the ground by screwing a 30 in. length of 3 in. iron pipe to the bottom of the gage and planting the gage in a post-hole so that the top of the gage was flush with the surface of the ground. The method of mounting the gages may be seen in Fig. 2.3.

2.3 SHOT 8

The primary purpose of the tests conducted on Shot 8 was to check

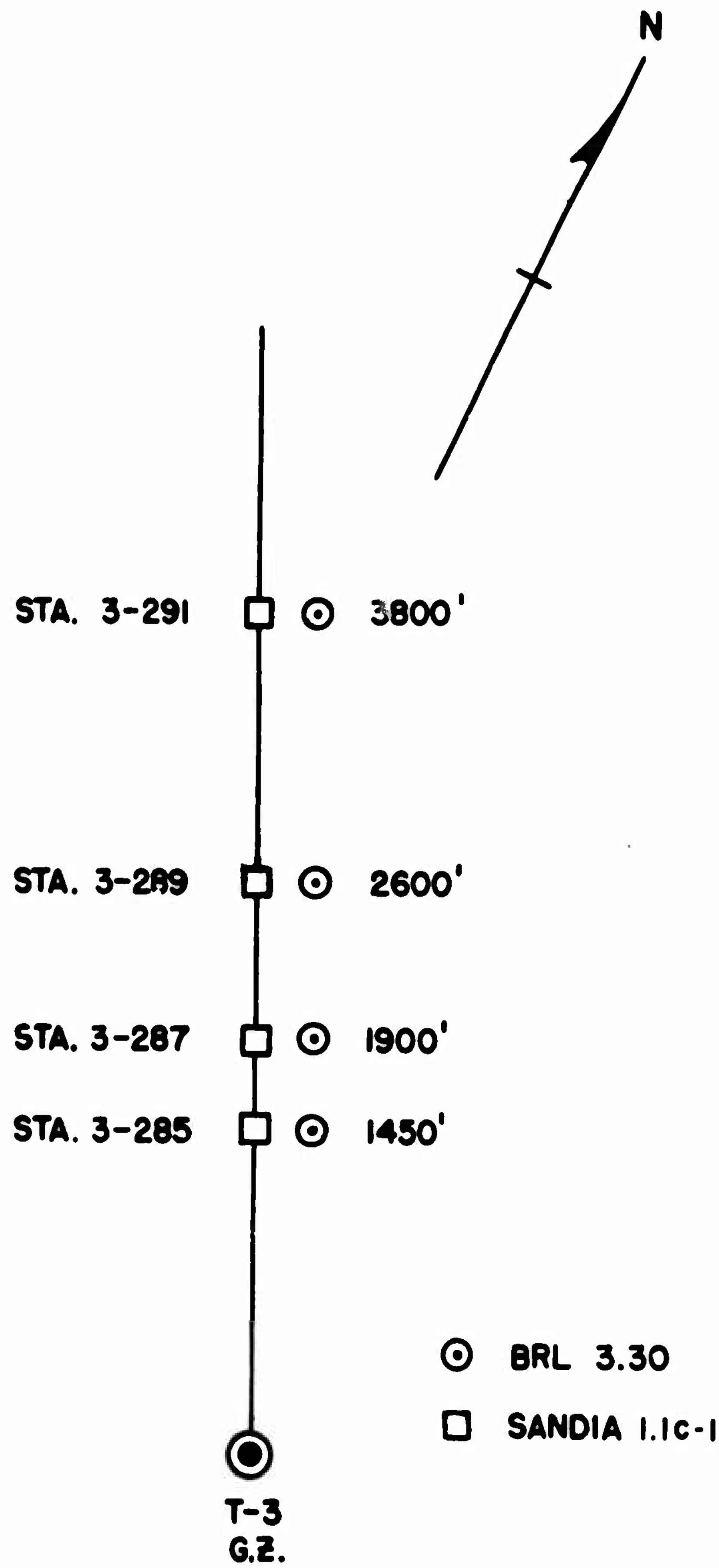

Fig. 2.1 Gage Layout For Shot 1 (T-3 Area)

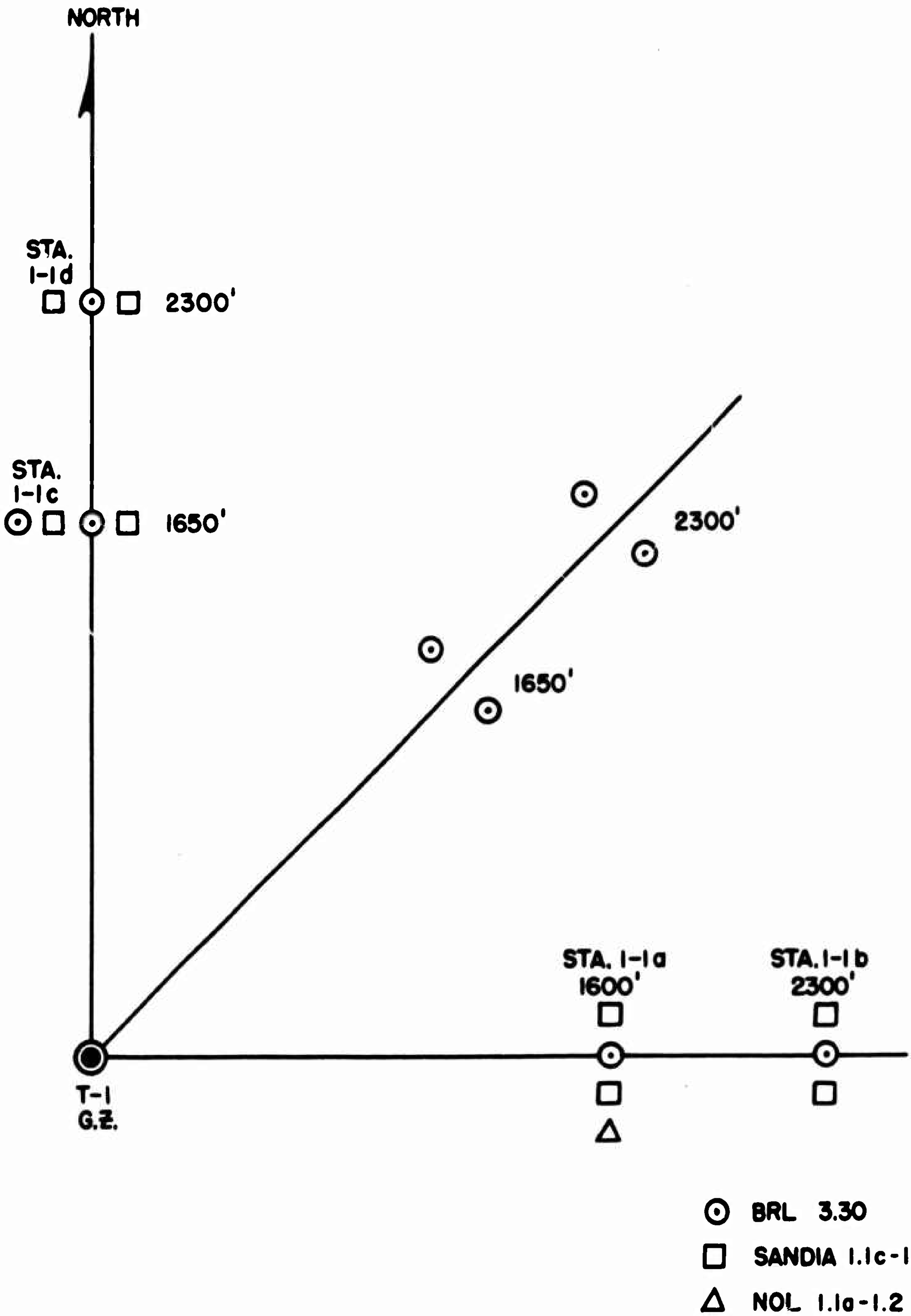

Fig. 2.2 Gage Layout For Shot 7 (T-1 Area)

for excessive disturbances on the records due to ground shock or acceleration in the 50 psi region. Project 3.30 was also asked to instrument two AEC air raid shelters for peak pressure measurements as back-up for the electronic measurements being made.

An experiment was also conducted to see if the self-contained gages could be used under water to measure the pressure-time phenomena in the air above the water. For this purpose, two gages were fitted with snorkle tubes which raised the Nylon and carbon paper initiation device above the surface of the water. This may be seen protruding from a barrel which was buried flush with the surface of the ground in Fig. 1.5. Two gages were placed flush with the surface of the ground at the same station for comparison. The gages in the water were about 3 ft below the surface. The pressure sensing element inlet was filled with water before the gages were submerged to eliminate any air bubbles in the pressure element. A peak-pressure recording gage was also tested under water.

The first two production models of the clock initiated pressure-time gages were tried on this test. They were mounted flush with the surface of the ground by digging a post-hole and placing the gage in the hole and filling in around the gage with loose soil.

On Shot 8 the Civil Effects Test Group (CETG) requested Project 3.30, two days before the shot, to use some pressure gages in their shelter as back-up measurements. Only peak pressure gages were used inside due to the initiation problem of the "A" type gages and the difficulty in mounting the clock initiated gages on such short notice. Two peak pressure measurements were made on the inside of shelter 3.602 and two outside at ground level. Only one peak pressure measurement was made inside of shelter 3.601.

The distance limitations of the thermal initiation triggering devices were also tested on this shot. The location of all gages and types are shown in Fig. 2.4.

2.4 SHOT 9

The gages, which were used on Shot 9, were installed partly to take measurements as a back-up system for the electronic measurements made by Project 3.28.1 and partly as a set of comparative measurements to test the gages against other systems of instrumentation. The gage location for Shot 9 may be seen in Fig. 2.5.

The gages were mounted in several different ways for this test. Fig. 2.6, shows a gage beside the hole in the front face of a test structure. Other gages were used in the roofs and rear faces of structures, under test vehicles, and for ground surface measurements. Some of the ground surface measurements were made at stations where Stanford Research Institute (SRI) had electronic ground surface measurements of air pressure. Another blast line was installed through the stabilized areas southwest of ground zero for comparative measurements with the indenter gages used by Naval Ordnance Laboratory (NOL).

2.5 SHOT 10

The gages used on Shot 10 were installed for the purpose of making measurements for Projects 3.28.1 and 3.21 and for comparative measurements with other types of instrumentation.

Most of the gages used on this test were installed flush with the surface of the ground for the purpose of measuring the air pressure-time phenomena at ground surface. A blast line was installed for Project 3.21 through the array of 57 mm guns. Six gages were used in the walls of two slit trenches to measure the pressure-time phenomena there and to compare with the gages installed there by NOL. Slit trench gage locations may be seen in Fig. 2.7. Four gages were installed near the animal shelters for comparative measurements with the self-contained gages used by NMRI. Two gages were installed in a barrel of water for comparative measurements with the self-contained gages used by NOL. Two gages were also installed for ground surface measurements at this location. The gage lay-out for Shot 10 may be seen in Fig. 2.8.

Fig. 2.3 Pressure-Time Gage Installed for Ground Surface Measurements and the Method of Anchoring in the Ground

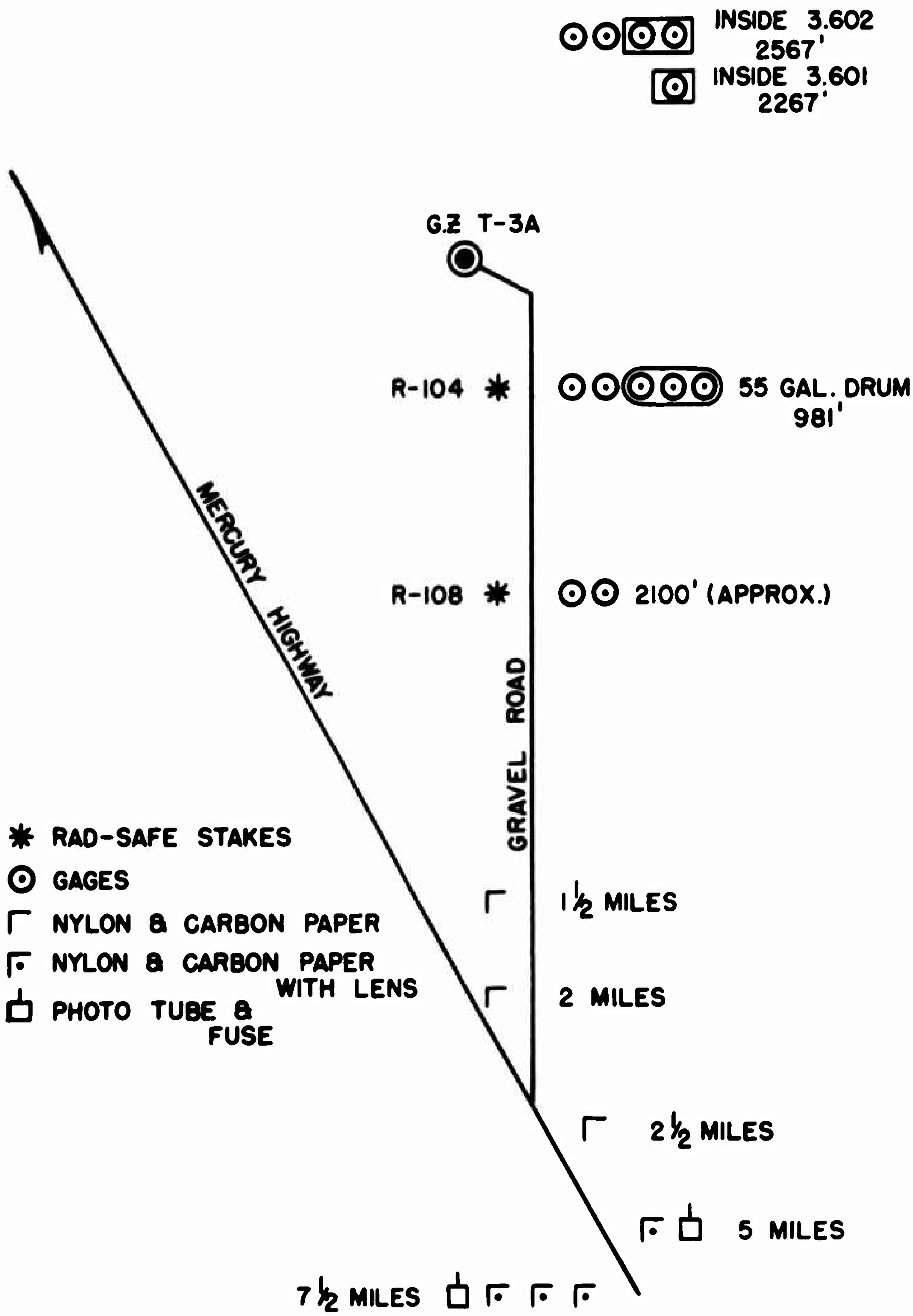

Fig. 2.4 Gage Layout For Shot 8 (T-3A Area)

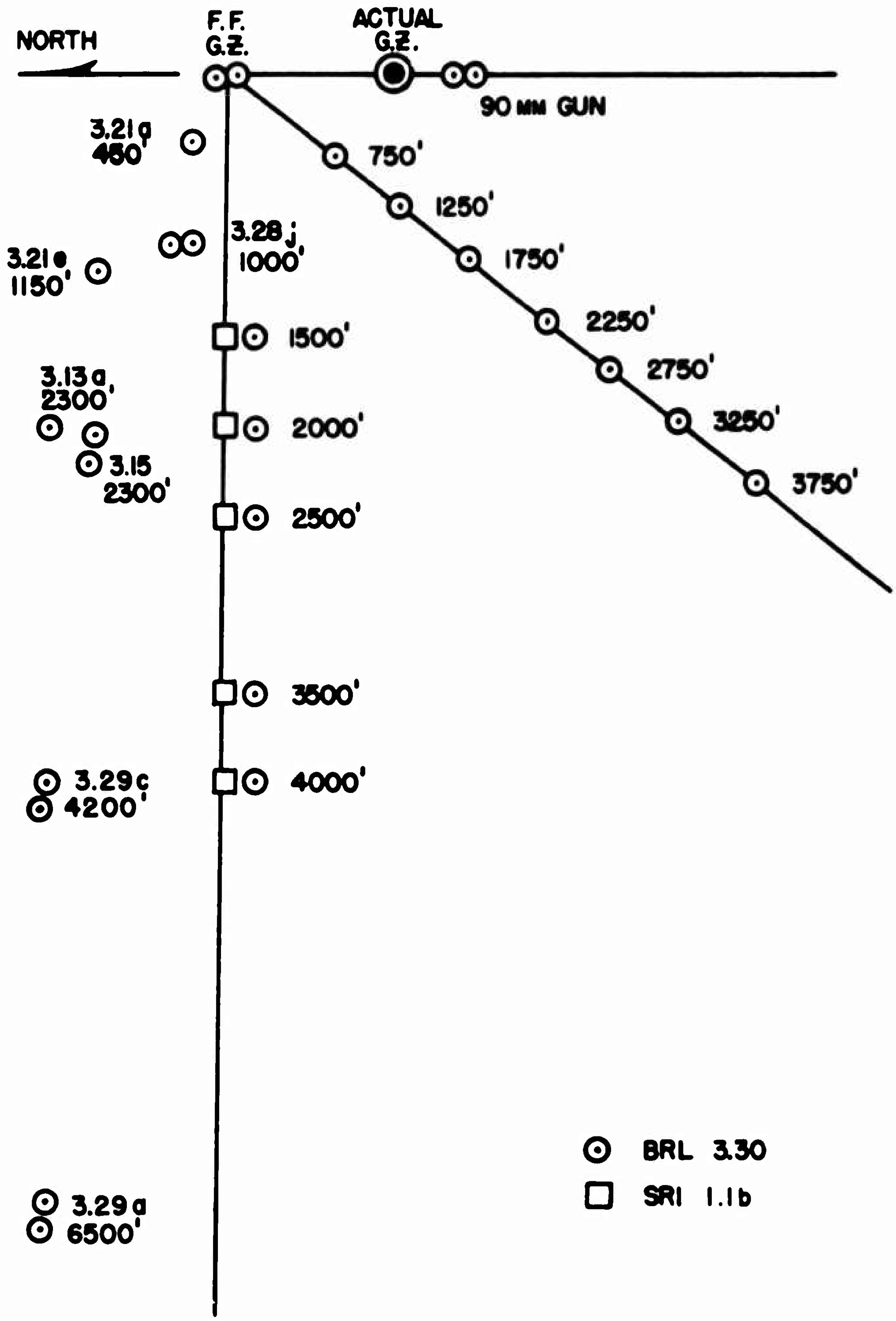

Fig. 2.5 Gage Layout For Shot 9 (Frenchman Flat)

Fig. 2.6 Gage and Mounting Hole as Used in the Front Face of a Structure

Fig. 2.7 Field Force Trench and Gage Location

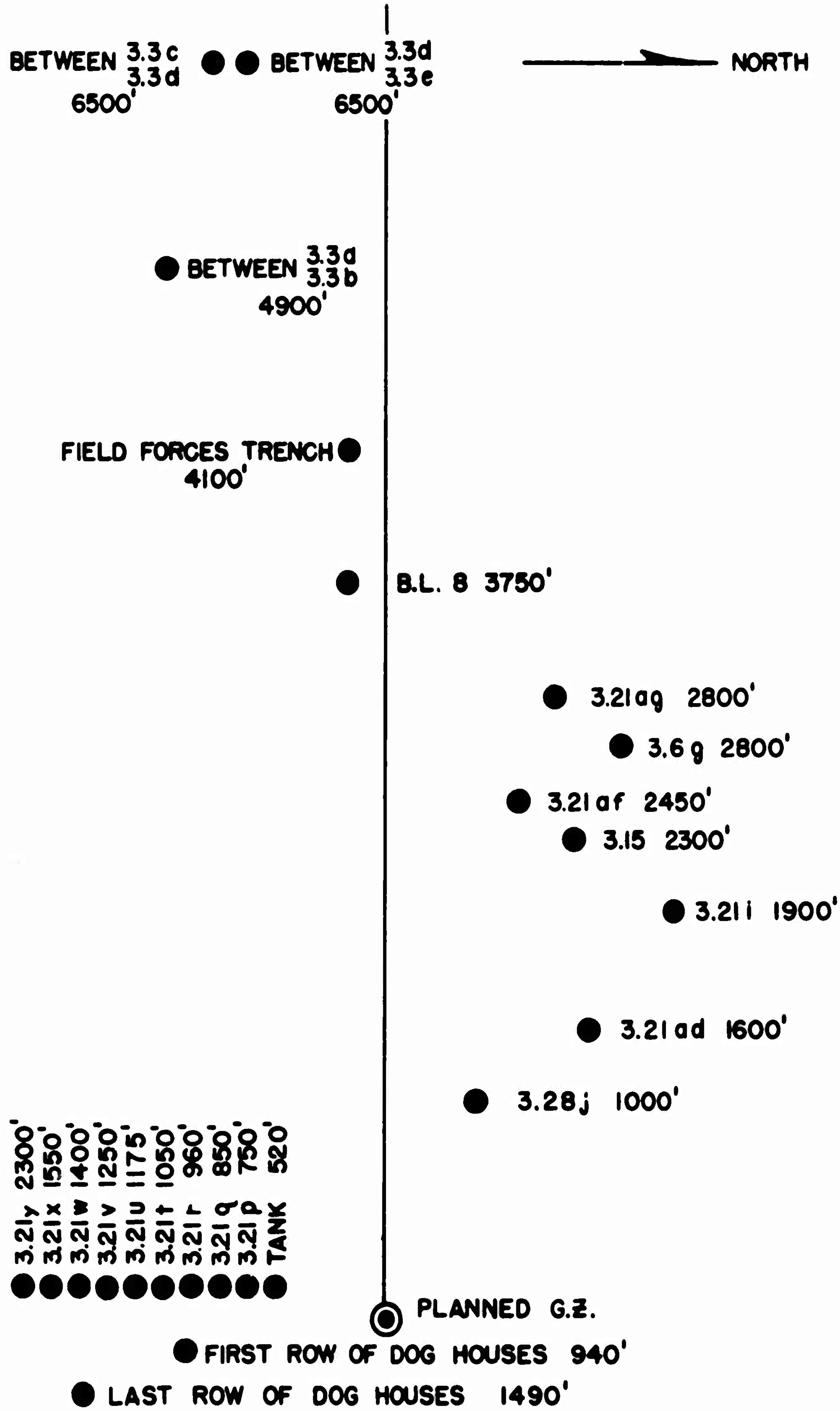

Fig. 2.8 Gage Layout For Shot 10

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2.6 SHOT 11

The primary purpose of the instrumentation on Shot 11 was to compare the self-contained gages with each other and with the electronic measuring equipment used by SRI along the main blast line. Two to six gages were used at each of 11 stations. The gage locations for Shot 11 are shown in Fig. 2.9.

Twelve gages were used on a blast line at 90 degrees to the main blast line to determine the possible difference in the shock wave at ground surface which might occur over terrain of a type different from that along the blast main line.

Seven gages were installed in an AEC air raid shelter for Project 24.1 as primary air pressure-time measurements. Two "C" type gages were mounted in an inner chamber where animals were exposed and three were mounted in an outer chamber with two peak pressure gages. The outer chamber and two gage locations are shown in Fig. 2.10.

One gage was installed on a 10 ft pole close to ground zero to measure the free air pressure in the region of regular reflection. This gage installation may be seen in Fig. 2.11.

One gage was modified to attempt to measure the differential pressure, "q," of the shock wave. This gage installation may be seen in Fig. 1.6.

One gage was modified to use a remote initiating device. Instead of the clock starting the recorder by closing a microswitch, the microswitch was held open by Nylon thread and carbon paper. A lens was used to insure the melting of the Nylon. The lens, Nylon, and carbon paper and the microswitch were mounted as a unit in a small metal box at some distance from the gage. With this type initiation device a gage with an electric motor drive can be used inside of structures, under water, underground and locations where a direct thermal initiating device would not work.

2.7 DATA REDUCTION EQUIPMENT

The recovered recording discs were examined in the field under a small microscope which had a 0.1 in. reticule scale with 0.001 divisions. It was more satisfactory to have an illuminated ground glass screen on which to place the record blank for examination by the microscope. The maximum deflection was measured directly and by consulting a curve of deflection vs pressure for the pressure sensing element with which the record was made, the maximum pressure was obtained. The pressure at any other point along the pressure-time curve was determined in the same manner.

In order to trace the record easily a 35 mm slide projector was used to project the records on a screen with magnifications up to 40 to 1. With a standard 200 watt projector, the records were viewed in a slightly darkened room with no difficulty.

Photographic reproduction of the records is also possible and has been used to present the pressure-time records in Figs. 3.3, 3.4, and 3.5. A tool makers microscope was used to magnify the records and a 4 by 5 in. Speed Graphic camera was used to make the negatives.

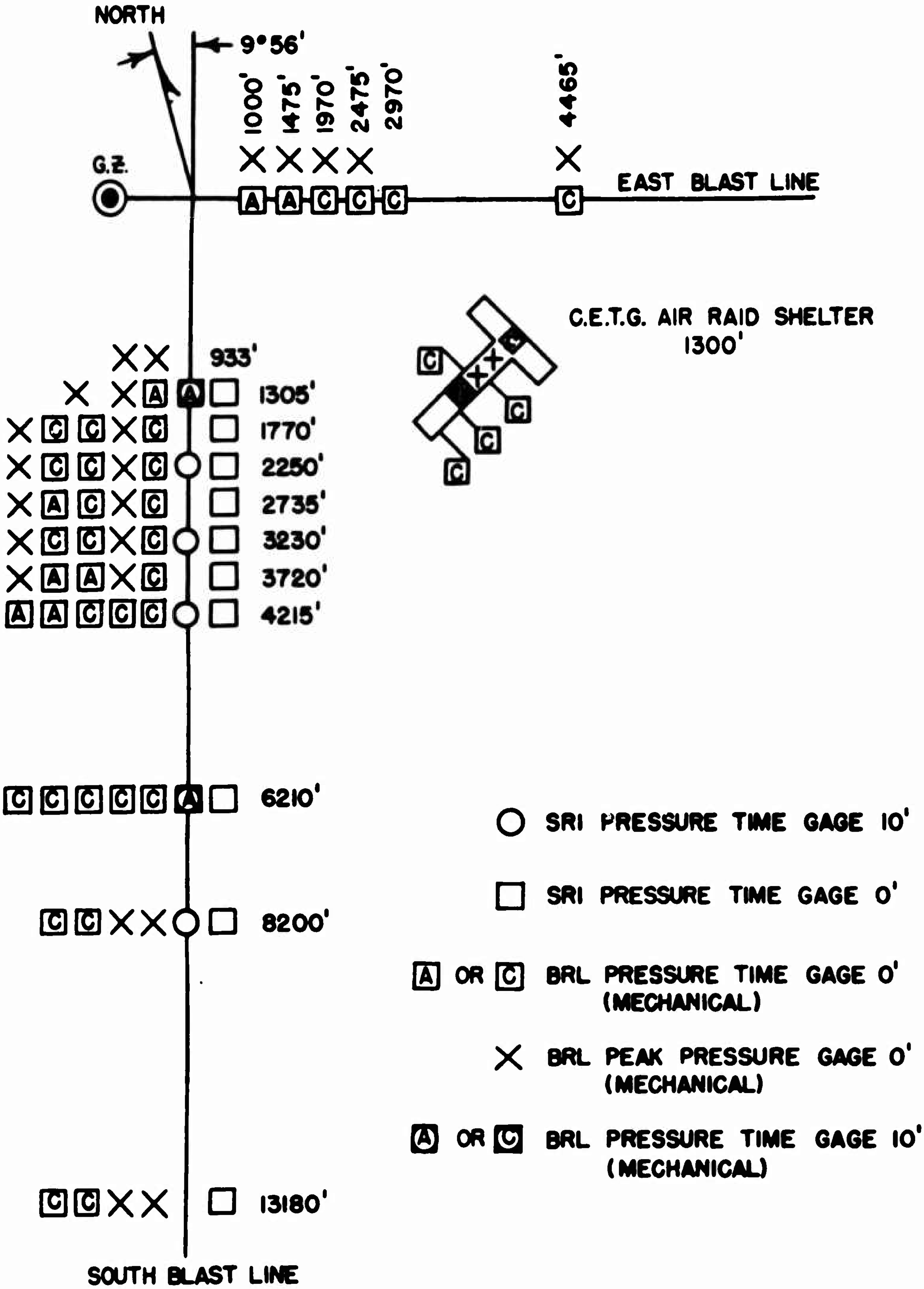


Fig. 2.9 Gage Layout for Shot 11 (Area T-7-3)

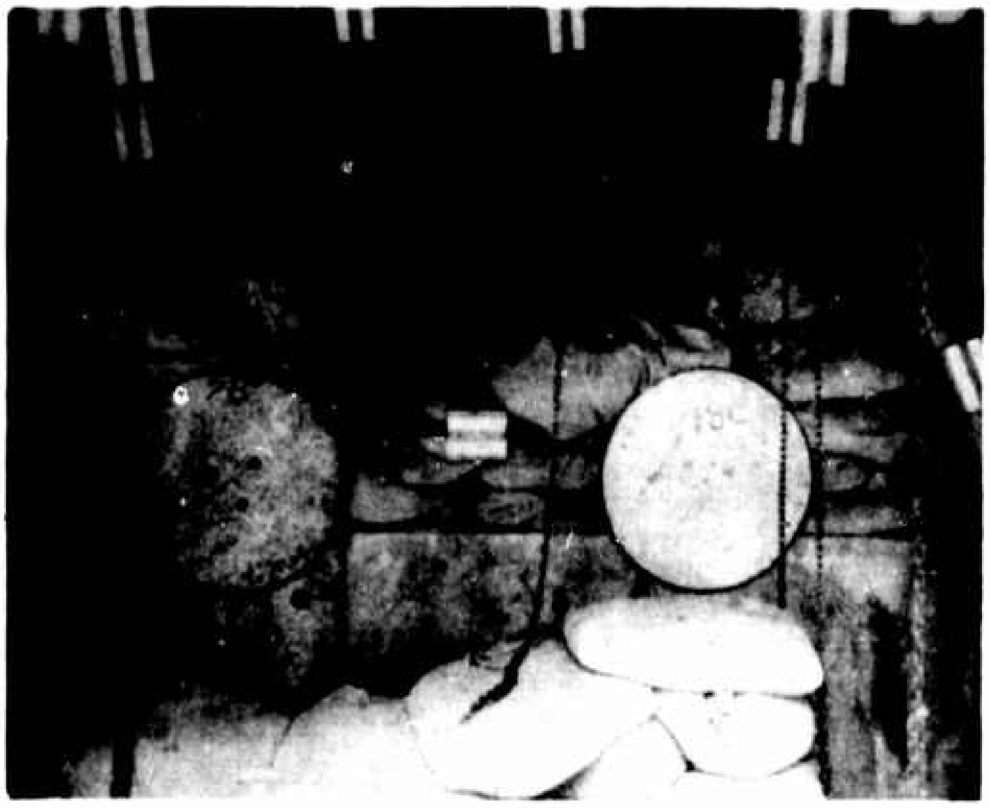


Fig. 2.10 Outer Chamber and Two Gage Locations in the Project 24.1 Test Shelter

Fig. 2.11 A Pressure-Time Gage Installed on a 10 ft Pole for Free Air Measurements

CHAPTER 3

RESULTS

3.1 SHOT 1

The purpose of the tests conducted on Shot 1 was to determine the feasibility of using the nylon and carbon paper initiation system to start the gage recorders when the thermal radiation reached the gage and prior to the arrival of the shock wave. Although two of the gages did not run because of mechanical failures, the test was a success in proving the possibility of using this initiation system.

The data obtained on this test are tabulated in Table 3.1. There is a direct comparison between the data obtained from these gages and the electronic measurements made by Sandia Corporation. 1/ In comparing the two, it must be remembered that these were prototype gages, hurriedly constructed primarily to test the initiation system. There were no provisions in the gages for temperature compensation, and the gage cases were sealed by spraying the cracks with Plastikote. In spite of the crudeness of the gage, fairly good results were obtained.

At Station 3-285 which was a ground distance of 1450 ft the gage did not start and, therefore, only a peak pressure measurement was made. However, there were indications on the record that two shocks were present and the overpressure of one was 16.4 psi and the other was 14.6 psi. The pressure-time records obtained at 1900 ft and 3800 ft show wave shapes very similar to those obtained by Wiancko 3 PAD variable-reluctance sensing elements and Consolidated 3-kc carrier-amplifier recording System D, used by Sandia Corporation. Comparison of records made at 1900 ft is shown in Fig. 3.1.

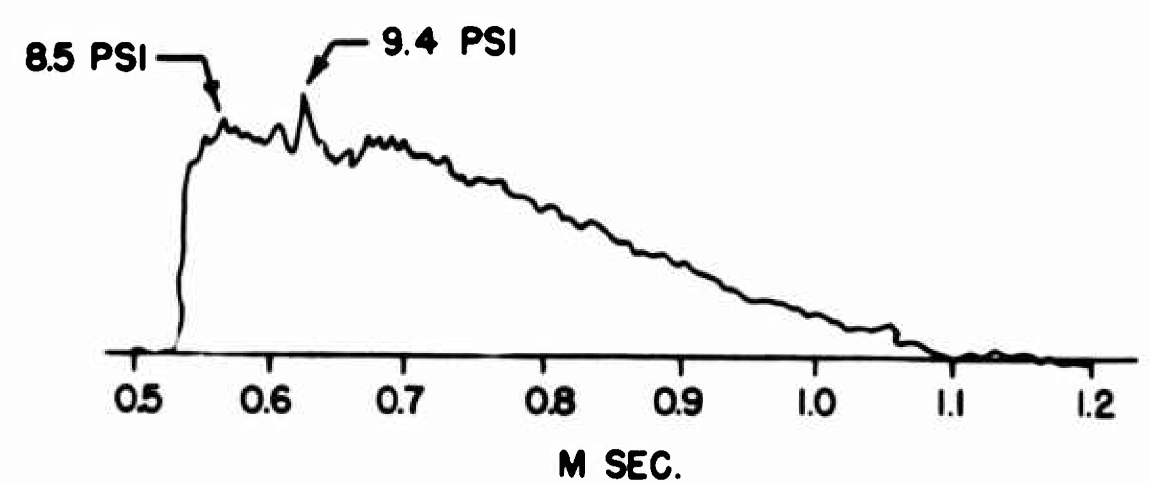
3.2 SHOT 7

After Shot 1 indicated the possibilities of these gages, eight more were built on a slightly different pattern. These gages were used on Shot 7 for comparative measurements with the ground surface

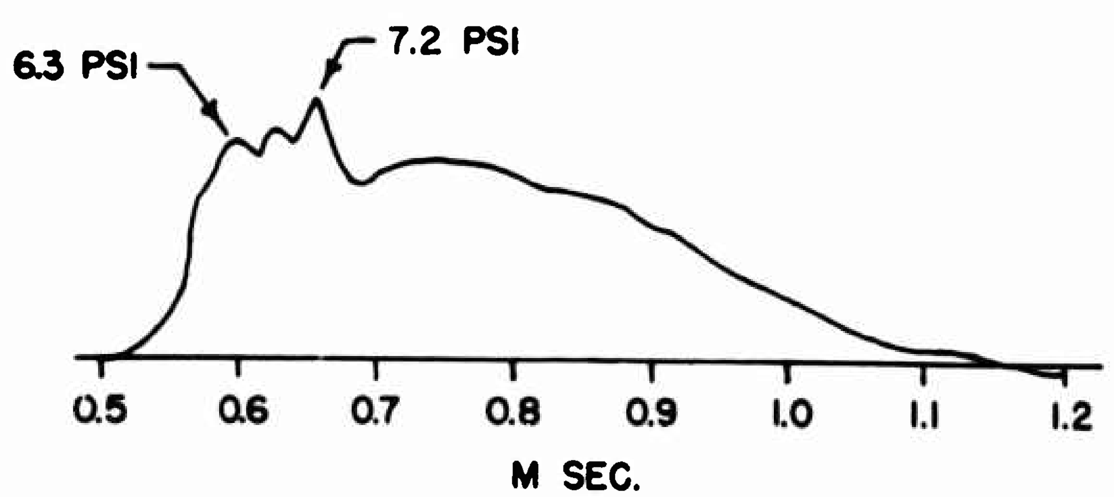
TABLE 3.1 Shot 1 Data

Station No.	Gage	Ground Distance ft	BRL Overpressure Peaks (psi)		Sandia Overpressure Peaks (psi)	
3-285	3	1450	14.6*	16.4*	12.4*	14.2*
3-287	1X	1900	6.3*	7.2*	8.5*	9.4*
3-289	4	2600	-	8.9	4.3	9.4
3-291	2X	3800	4.0	-	4.4	-

*Double entries here are dual prominences in the first general maximum of signal.



SANDIA 1.1c-1



BRL 3.30

Fig. 3.1 Comparison Of Electronic and Mechanical Gage Measurements at Station 3-287 (1900') gages used by Sandia Corporation.[1] The objective of the experiment was to measure the blast asymmetry of the particular device used. To do this, measurements were made at two radial distances, 1650 ft and 2300 ft along three blast lines. One blast line on which direct comparisons were made was sighted outward from the shielded side of the device. A second blast line on which comparisons were made with Sandia electronic measurements was at 90 degrees from the first line. The BRL instrumented a third line which was midway between the two main blast lines. The data obtained on this shot are tabulated in Table 3.2. This was the first test where the gages were installed in the ground with a 3 ft length of 3 in. pipe attached to the gage as a ground anchor. This method of mounting the gages was successful for all pressures encountered on this test.

The nylon and carbon paper initiation system was used on all of the gages and the system worked very well; however, the mechanical difficulty in these new gages caused malfunctioning of 10 out of 12 gages. Where the gage did not start, the recorder still recorded peak pressure but no pressure-time was obtained. Two of the gages did start and these had pressure-time records.

The malfunctioning of the gages was caused by a weak spring on the trigger rod which started the recorder when the nylon melted. One strand of nylon thread was used to hold the triggering rod on Shot 1 and 7. This meant a weak spring was necessary, otherwise the nylon would stretch and trigger the gage prematurely. Because of the weak spring, any binding in the shaft or any dirt in the trigger rod opening was likely to cause a malfunction.

After this test, the gages were thoroughly over-hauled, cleaned, and reassembled. Stronger springs were added to the trigger rods and a block and tackle winding of nylon thread was used. When used in this manner, if one thread melted the gage would trigger, and a more positive action was obtained by using the stronger springs.

3.3 SHOT 9

The purpose of the tests conducted on Shot 9 was to take back-up measurements for Projects 3.28.1 and 3.21 and to make comparative measurements with other systems of instrumentation. A total of 29 gages were installed for this test. The data obtained are tabulated in Table 3.3. It should be noted that many of the deflections measured were quite small because only high pressure elements were available and most of the pressures measured were small. The accuracy of the pressures obtained was ± 20 percent for 0.005 deflections and the accuracy of pressures obtained from a 0.010 to 0.050 in. deflection was ± 10 percent. A pressure vs distance from ground zero curve is shown in Fig. 3.2. This curve also shows the peak pressures vs distance measurements made by SRI,[2] and NOL,[3] using the electronic measuring equipment at ground surface stations. Pressure-time curves obtained in the front face and roofs of structures and along the ground are shown in Figs. 3.3, 3.4, and 3.5.

Ten out of eleven of the Nylon initiated gages started but one stopped when the shock hit the gage or shortly thereafter. One of these gages was used at a distance of 51,000 ft from the point of

TABLE 3.2 Shot 7 Data

Ground Distance ft	Gage	East Line Peak Pressure (psi)	Northeast Line Peak Pressure (psi)	North Line Peak Pressure (psi)
1650	BRL	49.0	39.0	25.5
	BRL	-	-	-
	Sandia	53.0	-	26.2
	Sandia	47.0	-	-
2300	BRL	21.6	14.0	15.0
	BRL	-	14.7	-
	Sandia	19.4	-	14.0
	Sandia	20.5	-	13.1

detonation. This gage was initiated manually and gave a good pressure-time record.

3.4 SHOT 8

The tests conducted on Shot 8 were for the purpose of determining whether or not the ground shock would cause a malfunction of the gage in the pressure regions of 50 psi. Two gages were installed flush with the surface of the ground at a distance of 981 ft from ground zero. Both the Nylon initiated gage and the peak-pressure gage operated successfully. The pressure-time and the peak pressure gages worked well under water and good agreement was obtained between the gages under water and the gages flush with the ground at that station. The tabulation of the data obtained on Shot 8 may be seen in Table 3.4.

Four peak-pressure and one pressure-time gage were installed as back-up measurements for CETG Project 24.1 in the two air raid shelters 3.601 and 3.602 and at ground level near the shelters. The pressure-time gage did not run but a peak pressure value was obtained. The peak pressure gages gave consistent results and compared well with expected results. These data are also tabulated in Table 3.4.

3.5 SHOT 10

The purpose of the tests on Shot 10 was the same as Shot 9. The remainder of the order of pressure sensing elements arrived and a better selection of ranges for expected pressures were available. The accuracy achieved by these pressure measurements should be of the order of $\pm$ 10 percent or less.

The tabulation of the data obtained on this test is shown in Table 3.5. The ground level distance vs pressure curve is shown in Fig. 3.6. Most of the gages were installed flush with the surface of the ground for this test except those specifically mentioned in the table as being used for other types of measurements.

TABLE 3.3 Shot 9 Data

Location Main Blast Line	Ground Range (ft) Original	Ground Range (ft) Corrected	Gage No.	Type Record	Deflection In. X10^{-3}	Peak Pressure BRL	Peak Pressure SRI	Peak Pressure NOL
Station								
F-214	0	814	13 B	P.P.	8.5	210	21.7	-
	0	814	10 B	P.P.	7.0	18.6	-	-
F-280	750	1102	-	-	-	-	-	18.3
F-217	1500	1694	17 B	P.P.	6.3	16.0	14.3	-
F-288	1750	1924	-	-	-	-	-	13.29
F-200	2000	2145	14 B	P.P.	5.0	12.5	11.2	-
F-201	2250	2377	-	-	-	-	-	11.29
F-202	2500	2615	18 B	P.P.	4.2	11.0	10.4	-
F-203	2750	2852	-	-	-	-	-	11.26
F-204	3000	3094	-	-	-	-	10.5	-
F-205	3250	3337	-	-	-	-	-	10.37
F-206	3500	3579	20 B	P.P.	4.0	10.2	7.98	-
F-207	3750	3824	-	-	-	-	-	8.55
F-208	4000	4067	16 B	P.P.	26.5	8.8	7.42	-
F-289	4250	4315	-	-	-	-	-	7.42
Southwest								
Line	1250	825	9 A	P.T.	67.0	22.7		
"	1750	1265	7 A	P.T.	34.3	18.7	No	
"	2250	1690	2 A	P.T.	46.2	15.4	Comparison	
"	3250	2640	3	P.T.	33.0	12.0		
"	3750	3160	4	P.P.	72.5	11.2		
Ground at 90mm Gun.	1250	630	4 B	P.P.	8.0	20.5		
In Pit at 90mm Gun.	1250	630	3 B	P.P.	6.6	18.0		
Front Face of Bldg 3.29 C	4200	4490	5 A	P.T.	64.0	21.0		
Front Face of Bldg 3.29 A	6500	6650	8 A	P.T.	37.0	11.3		
Roof of Bldg 3.15	2300	2730	4 A	P.T.	38.3	11.8		
Front of Bldg. 3.15	2300	2730	6 A	P.T.	67.0	22.7		
Roof of Bldg 3.13	2300	2790	12 B	P.P.	3.8	9.5		

TABLE 3.3 Shot 9 Data (cont'd)

Location Main Blast Line	Ground Range (ft) Original	Ground Range (ft) Corrected	Gage No.	Type Record	Deflection In. $X10^{-3}$	Peak Pressure BRL
Inside						
3.28 j	1000	1515	14B	P.P.	1-6	0.3-0.8
3.21 e	1250	1640	15B	P.P.	4.3	11.5
Under a Truck 3.21a	700	1195	9B	P.P.	8.1	25.0
	51,000	-	2X	P.P.	17.0	0.46
Roof of shelter 3.28 j	1000	1515	6B	P.P.	5.3	14.0
Roof Bldg 3.29c	4200	4490	3A	P.T.	33.2	9.6
Roof of Bldg 3.29a	6500	6650	1B	P.P.	14.5	4.8

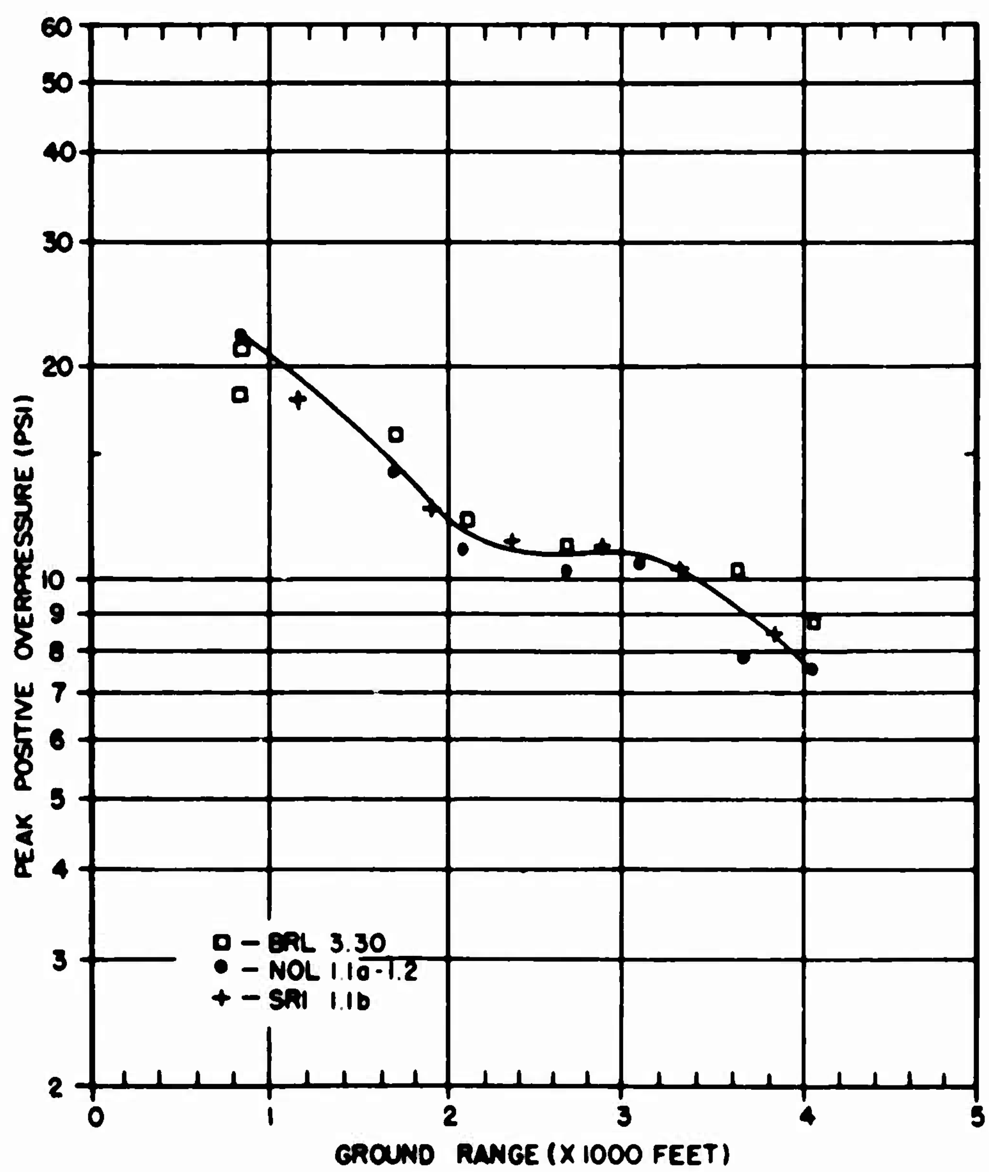


Fig. 3.2 Ground Surface Pressure Vs Distance, Shot 9

~~SECRET RESTRICTED DATA~~

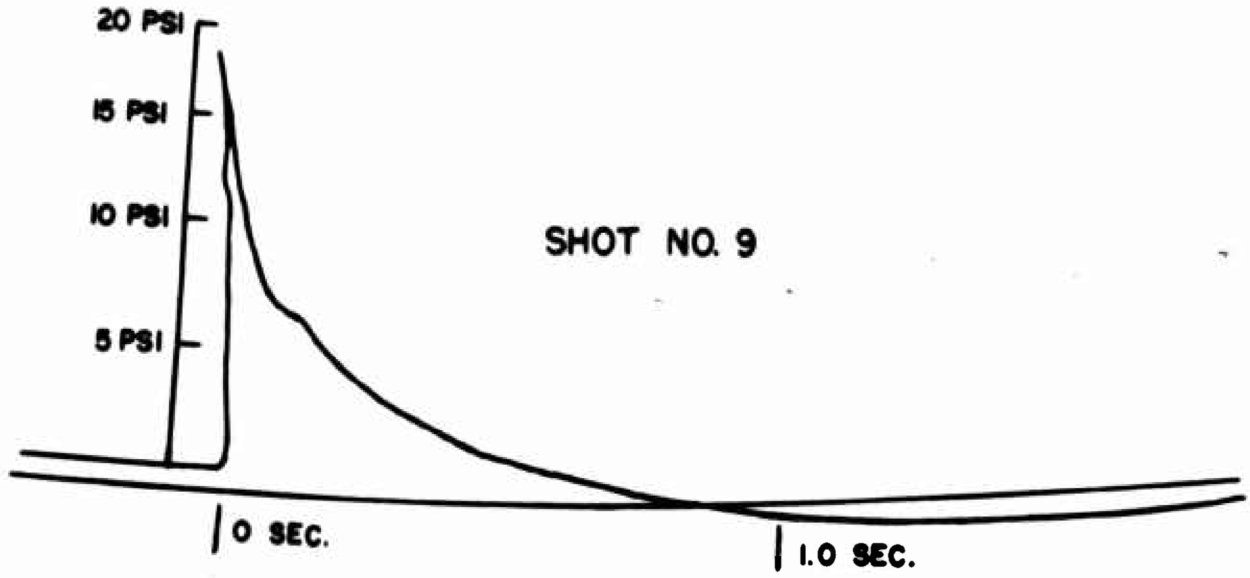


Fig. 3.3 Pressure-Time Record from Front Face of Structure 3.15, 2730 ft

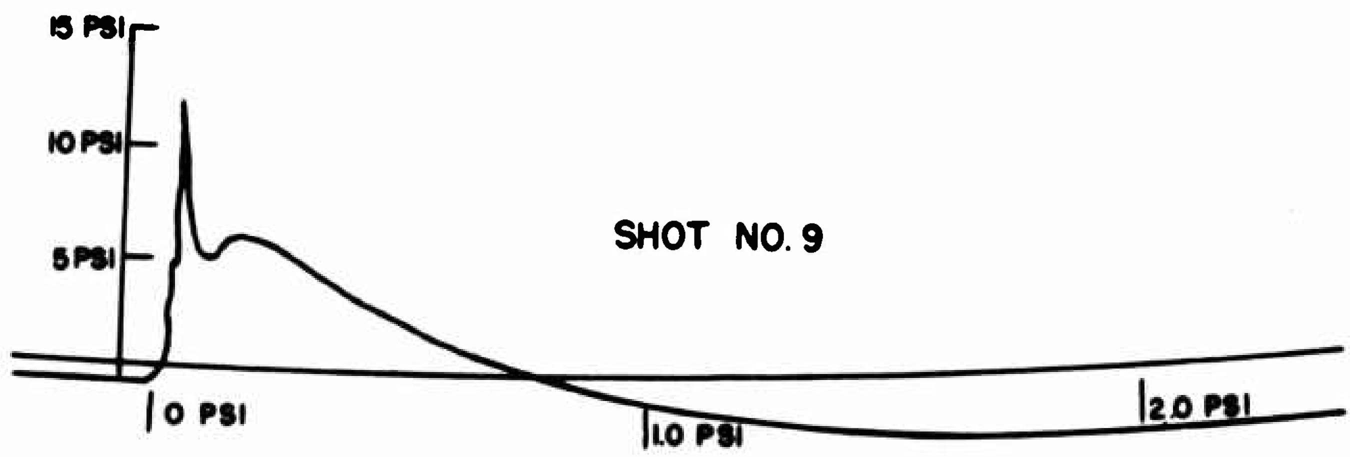


Fig. 3.4 Pressure-Time Record from Roof of Structure 3.15

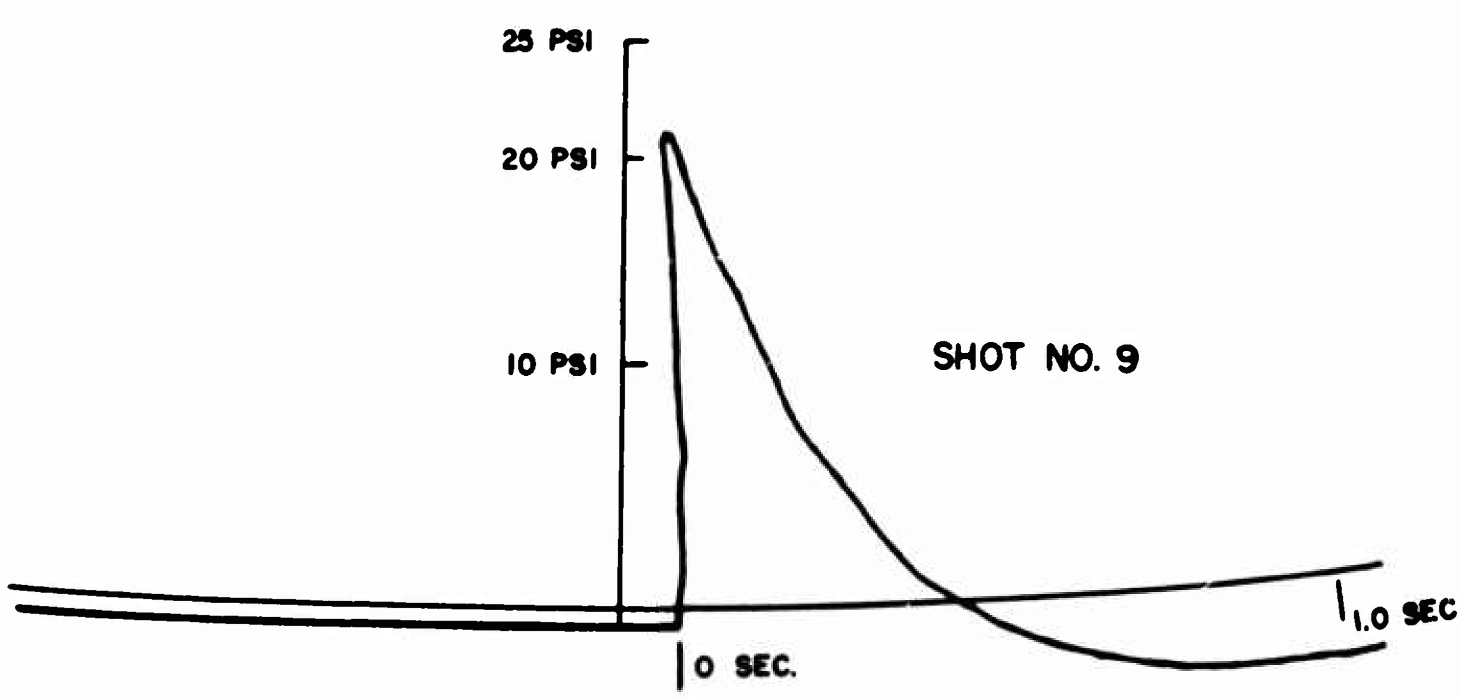


Fig. 3.5 Pressure-Time Record, Ground Surface, 825 ft

TABLE 3.4 Shot 8 Data

19 May 1953 T-3A Area Tower Shot

Gage No.	Distance From GZ (ft)	Location of the Gage	Peak Pressure (psi)
12B	2567	Inner end of 3.602	9.6 near waist height
17B	2567	Inside first room 3.602	9.9 near the ceiling
10B	2587	Ground near 3.602	11.0 ground level and flush
4B	2267	Inner end of 3.601	10.2 near waist height
1C	2100	Across the road from Radsafe stake No. 108	11.4 ground level and flush
2C	2100	as above	11.1 ground level and flush
7A	981	Across the road from Radsafe stake No. 104	56.0 in barrel, under-water
6A	981	As above	58.2 in barrel, under-water
9B	981	As above	64.5 in barrel, under-water
3A	981	As above	56.0 ground level and flush
20B	981	As above	51.0 ground level and flush

Nylon and Carbon Paper, stretched by a light string and exposed to the thermal radiation, were used to determine the limits at which this type of initiation could be used.

Gage No.	Distance from Ground Zero	Results
1	1-1/2 miles	Triggered
2	2 miles	Triggered
3	2-1/2 miles	Triggered

Nylon and Carbon Paper, stretched by a small string, were used at the focal point of a small lens of the type used in jeweler's eye piece. The lens was 29/32 inches in diameter with a focal length of 3-1/2 inches.

Gage No.	Distance from Ground Zero	Results
1L	5 miles	Triggered
2L	7-1/2 miles	Triggered
3L	7-1/2 miles	Triggered
4L	7-1/2 miles	Triggered
5L	9 miles	Did not trigger*

Gage No.	Distance from Ground Zero	Results
6L	25 miles	Did not trigger**

* The carbon paper blew off this gage.

**The carbon paper was marked and two strands of the three-strand nylon thread were burned. It is thought that with a slightly better lens the initiation system should work even at this distance.

A ground level blast line was installed through the array of 57mm guns being tested by Project 3.21. This blast line had the nearest station to ground zero at 350 ft from the actual ground zero. One of the pressure-time gages used at this station had the 150 psi maximum range pressure sensing element blown apart by the pressure. It was estimated that the pressure level at this station was in the vicinity of 400 to 500 psi. Although the pressure element was destroyed, the gage was not otherwise damaged except for sand which was blown into the gage through the pressure inlet opening. This is significant, in that it indicates these gages can be used at higher pressures than have been accomplished so far. Other stations on this line measured pressures as high as 202 psi. The 202 psi pressure was measured with a 150 psi element and the calibration curve had to be extrapolated, but the measurement is thought to be accurate to + 20 percent or less. Nylon initiated pressure time gages were used at distances of 645 and 715 ft from actual ground zero and they both started prior to the arrival of the shock wave and recorded pressure-time curves which had peak pressures of 202 and 112 psi. These curves were somewhat irregular and indicate that the gages were violently shaken by the shock wave. The slow speed of the turn-table and mechanical difficulties render these curves of small value for actual pressure-time data but they do show that pressure-time records can be taken with self-contained gages in this region, and, with an improved gage, useful data could be obtained.

Six clock initiated pressure-time gages were used in two of the Project 3.9 field forces slit trenches. These were recessed in the walls of the trench with the face plates flush with the walls. The curves were in good agreement with the data obtained with the Wiancko gages used by NOL in these trenches. A direct comparison of a pressure-time curve recorded by a BRL mechanical gage in the rear wall of a slit trench with one obtained by the NOL electronic system, where the gage was flush with the floor of the trench, is shown in Fig. 3.7. It was of interest to note that the pressures measured in the slit trenches were approximately twice as high as the pressures on the ground surface at the same distance from ground zero.

Four gages were used for comparison with the self-contained pressure-time gages used by NMRI for measurements in their animal shelters. The gages installed by NMRI for comparison blew away and were not recovered, making a comparison impossible.

Two gages were installed under water, similar to those tested in

TABLE 3.5 Shot 10 Data

Location	Ground Range (ft)	Gage And Element	Deflection In. $X10^{-3}$	Positive Peak Pressure			Remarks
				BRL	SRI	NOL	
Tank South of G.Z.	390	3A5-150	-	-	-	-	150 psi element blew apart.
	390	9B9-150	138.0	480	-	-	150 psi element overstressed. Calibration extrapolated.
F-280	674	-	-	-	-	140	
3.21 P	645	4A20-100	44.0	119	-	-	Good P - T record.
3.21 P	645	20B17-150	77.0	202	-	-	Good peak - curve extrapolated.
3.21 Q	715	5A7-100	42.0	112	-	-	Very short duration, Good Reading
3.21 Q	715	6B2-150	37.8	104	-	-	Good peak reading.
3.21 R	850	13B10-100	29.0	76	-	-	Questionable reading.
3.21 T	900	10B12-150	35.3	97.5	-	-	Good peak reading.
F-216	920	-	-	-	71.9	-	
3.21 U	1045	23B2-50	50.0	60.0	-	-	Good peak reading.
3.21 V	1100	15B3-50	32.2	36.8	-	-	Good peak reading.
3.21 W	1265	12B4-35	77.5	26.0	-	-	Good peak reading.
F-282	1282	-	-	-	-	37.2	
3.21 X	1415	17B5-35	75.5	25.2	-	-	Good peak reading.
F-217	1417	-	-	-	15.0	-	
3.21 ad	1600	3T2-35	45.0	17.2	-	-	High frequency oscillation.
F-288	1749	-	-	-	-	9.78	
F-200	1916	-	-	-	8.6	-	
3.21 i	1920	8A2-15	32.5	11.5	-	-	Peak reading questionable.
3.21 y	2140	1B3-15	31.2	10.5	-	-	Good peak reading.
F-201	2229	-	-	-	-	8.72	
3.21 af	2415	9A-22-10	47.0	10.3	-	-	Good reading - Precursor evident.
F-202	2415	-	-	-	8.07	-	
F-203	2666	-	-	-	-	8.21	
3.21 ag	2770	42-12	45.0	7.0	-	-	(Good trace; no evidence of precursor)
F-204	2916	-	-	-	7.08	-	

TABLE 3.5 (Cont'd) Shot 10 Data

Location	Ground Range (ft)	Gage and Element	Deflection In. X10^{-3}	Positive Peak Pressure BRL	Positive Peak Pressure SRI	Positive Peak Pressure NOL	Remarks
NMRI							
First Row of	860	3C9-50	52	60.5			Flat Top Wave-Questionable
Dog Houses	860	16B6-35	96	34.0			Wrong Element Used-Questionable
Last Row of	1410	7C19-100	8	20.5			Small Deflection
Dog Houses	1410	8B5-25	40	23.0			Good Peak
NOL							
B.L.8 WATER	3710	7A4-150	-	-	-	-	Deflection Too Small
B.L.8 WATER	3710	22B3-10	31.5	6.8	-	-	Good Peak Reading
B.L.8 GROUND	3710	8C7-10	25.5	5.4	-	-	Good P-T Curve
B.L.8GROUND	3710	21B5-10	22.0	4.8	-	-	Questionable Base Line
F-207	3702	-	-	-	-	5.8	
F-289	4198	-	-	-	-	4.3	
FIELD FORCES							
SLIT TRENCH							
West of N. Trench	4020	9C8-10	41.0	8.8	-	-	Good P-T Record
South of N. Trench	4020	10C9-10	40.8	9.0	-	-	Motor Stopped Good peak
East of N. Trench	4020	11C11-10	41.0	8.9	-	-	Good P-T Record
West of S. Trench	4020	6C9-5	52.0	8.5	-	-	Good P-T Record
South of S. Trench	4020	5C6-10	36.0	8.0	-	-	Motor Stopped Good Peak

TABLE 3.5 (Cont'd) Shot 10 Data

Location	Ground Range (ft)	Gage and Element	Deflection In. $X10^{-3}$	Positive Peak Pressure			Remarks
				BRL	SRI	NOL	
East of S. Trench	4020	12C3-5	48.0	8.1	-	-	Good P-T Record
Inside 3.28J	985	161-10	3	1.0	-	-	Small Deflection-Questionable
Inside 3.28J	985	14B3-100	1.2	2.0	-	-	Small Deflection- Questionable
Roof 3.28J	985	3B11-100	14	37.0	-	-	Shows good vortex
Back Face 3.15	2310	2C8-35	39	11.4	-	-	Good Record
Front Face 3.15	2280	2A9-35	40	12.5	-	-	Good Record
F-209	4415	-	-	-	4.07	-	
F-290	4694	-	-	-	-	3.56	
Between 3.3a & 3.3B	4785	5B1-5	22.7	3.45	-	-	Good Peak Reading
F-210	4915	-	-	-	3.42	-	
F-291	5440	-	-	-	-	3.00	
F-211	5915	-	-	-	2.33	-	
Between 3.3c & 3.3d	6260	24B7-5	14.4	2.08	-	-	Good Peak Reading
F-292	6934	-	-	-		1.69	

Note: BRL Gages were not along main blast line on this shot. Differences in comparative pressures may be due to non-asymmetry of the shock wave. See Fig. 2.8.

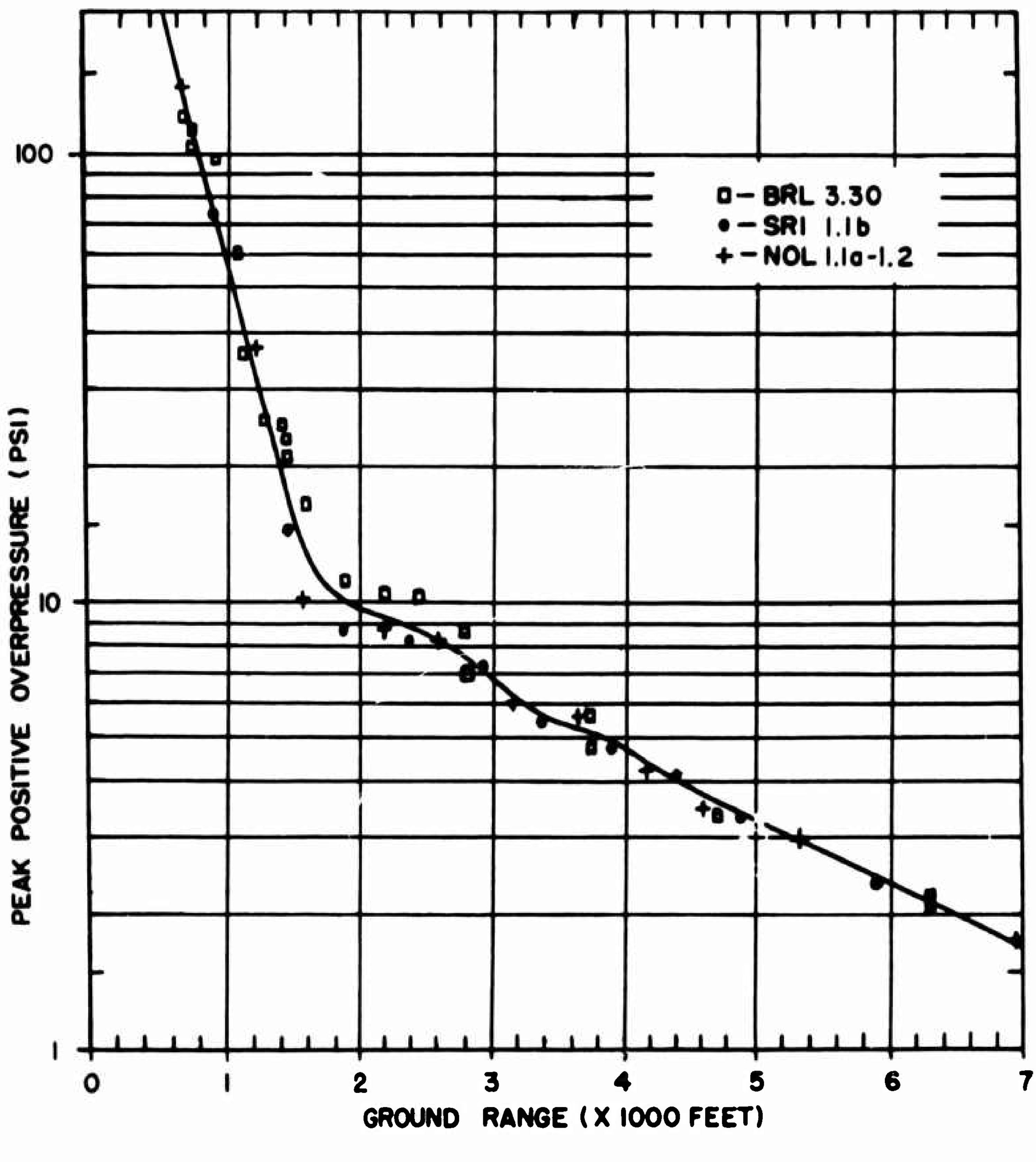


Fig. 3.6 Ground Surface Pressure Vs Distance, Shot 10

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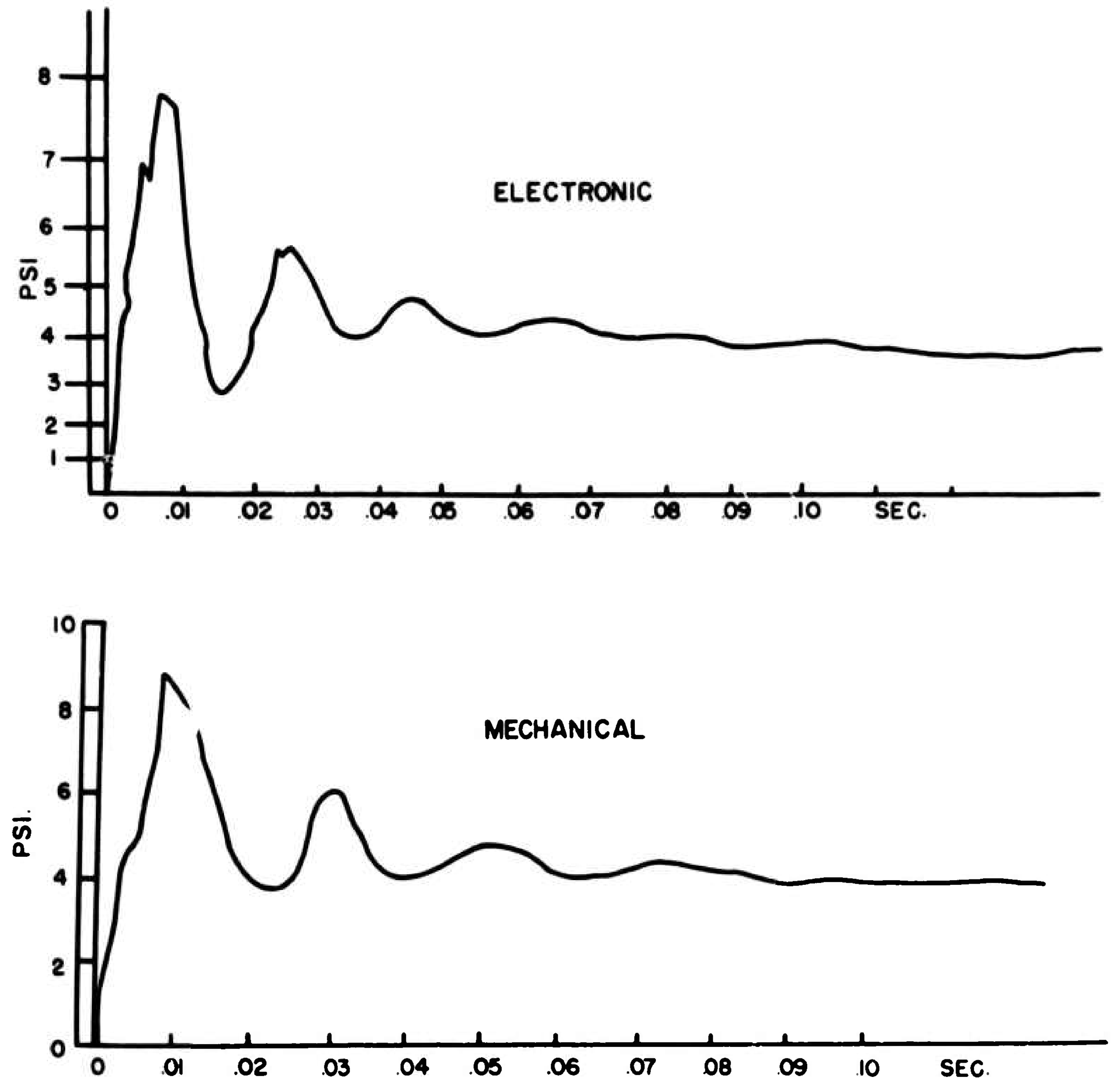


Fig. 3.7 Comparison of Electronic and Mechanical Pressure-Time Records Taken on Shot 10, in a Slit Trench at 4020 ft

Shot 8 for a comparison with a self contained gage used by NOL. The gages ran but because of an error in selection of the pressure sensing element in the pressure-time gage, the deflection was so small on this record as to be useless.

One gage was used on this test at the observation post approximately 6.6 miles from the point of detonation. This gage was held in a man's hand, face on to the blast, and the recorder was started manually. A pressure of 0.3 psi was recorded and a good pressure-time record was obtained.

3.6 SHOT 11

The data obtained on this test are tabulated in Table 3.6. The ground level pressure vs distance curve predicted for this shot is shown in Fig. 3.8. The points plotted on the figure are the average gage measurements at each station made by the self-contained gages and the individual ground level pressures measured by the electronic instruments used by SRI. Direct comparison of measurements was made on the south blast line. The east blast line was installed to test the possible difference in the curve over a different type of terrain. These points are not plotted on Fig. 3.8.

A direct comparison of the pressure-time records obtained at four stations together with the pressure-time records obtained by the electronic instrumentation at those stations are shown in Figs. 3.9 and 3.10.

In addition to the two blast lines installed on this test, seven gages were installed in a bomb shelter as part of CETG 24.1. While all of the gages on this test apparently ran, only two out of five had any pressure-time curves. The two peak pressure gages worked and gave readings comparable with the pressure-time records that were obtained. Nothing was found on the other pressure-time records. Usually, even if the gage did not run, a peak pressure was obtained. The only explanation possible was that the pressure inlets to the gages were plugged.

One gage was modified to make a differential pressure measurement between a pitot tube and the static pressure. This gage was not recovered.

Four nylon and carbon paper initiation devices with a lens for focusing the radiation on the nylon were installed to determine the approximate limits at which this system of initiation could be used.

TABLE 3.6 Shot 11 Data

SOUTH BLAST LINE (Ft From GZ)	GAGE AND ELEMENT	DEFLECTION (In X 10^{-3})	PRESSURE	REMARKS
1220	9B9-150	20.2	53.0	Good P.P.
1220	20B17-150	20.4	54.0	Good P.P.
1580	4A20-100	17.[illegible]	43.5	Good P.P.
1580	13B10-100	10.[illegible]	26.5	Good P.P.
1580	10B12-150	10.9	29.8	Good P.P.
2030	19C11-50	22.5	28.0	Fair P.T. Curve
2030	12C5-50	20.0	22.2	Poor P.T. Curve
2030	23B2-50	17.4	19.8	Poor P.P.
2030	15B3-50	15.2	17.0	Fair P.P.
2500	22C4-25	19.0	11.2	Good P.T.
2500	23C3-25	19.4	11.4	Good P.T.
2500	12B4-35	34.3	10.5	Good P.P.
2500	17B5-35	33.0	10.3	Good P.P.
2980	2A9-35	36.0	11.[illegible]	Good P.T.
2980	32C1-25	20.6	11.8	Good P.T.
2980	20C7-25	17.0	9.9	Fair P.T.
2980	16B6-35	36.4	11.9	Good P.P.
2980	4B3-35	40.6	11.8	Good P.P.
3465	14C12-15	37.5	11.7	Faint P.T. Trace
3465	15C19-15	38.1	12.2	Questionable P.T. Curve
3465	17C7-15	15.0	4.7	Record No Good
3465	1B3-15	34.0	11.5	Good P.P.
3465	1B9-15	6.1	1.9	Gage Case Leak
3950	8A2-15	26.7	8.2	Good P.T.
3950	9A22-10	41.5	9.1	Good P.T.
3950	33C4-15	21.0	6.9	Very Faint Trace
3950	22B3-10	44.1	8.7	Good P.P.
3950	21B5-10	38.5	8.2	Good P.P.
4445	26C18-15	24.5	7.8	Good P.T.
4445	24C20-15	25.8	8.3	Good P.T.
4445	11C11-10	-	-	No Record
4445	42-12	44.0	6.8	Fair P.P.
4445	1x1-12	-	-	No Record
6425	5C6-10	24.8	5.4	Good P.T.
6425	1C1-10	-	-	No Record
6425	10C9-10	24.5	5.4	Good P.T.
6425	8C7-10	25.4	5.4	Good P.T.
6425	9C8-10	24.7	5.3	Good P.T.
8415	16C2-10	25.5	4.0	Good P.T.
8415	25C13-10	17.8	4.0	Good P.T.
8415	7B4-5	28.2	4.0	Good P.P.
8415	19B10-5	23.8	3.6	Good P.P.
13410	28C6-5	16.3	2.35	Good P.T.

TABLE 3.6 (Cont'd) Shot 11 Data

SOUTH BLAST LINE (Ft from GZ)	GAGE AND ELEMENT	Deflection (In X 10^{-3})	PRESSURE	REMARKS
13410	5B1-5	13.6	2.0	Good P.P.
13410	24B7-5	17.2	2.5	Good P.P.
1250	6A14-150	25.8	67.5	P.P. Only
1250	6B2-150	25.2	67.0	Fair P.P.
1505	3A2-70	65.0	48.0	Poor P.T.
1505	18B8-100	13.3	34.5	Fair P.P.
2200	2C8-35	91.5	27.5	P.P. Only
2695	8B5-25	16.5	9.3	Good P.P.
3185	21C5-15	24.7	7.9	Faint Trace
4680	4C4-10	33.0	7.4	P.P. Only
4680	2B21-10	26.2	5.6	Gage Case Leak
C.E.T.G. 24.1 (1565 Ft)				
Wall	18C15-100	13.5	36.5	Poor P.T. Record
Inner Room	31C1-100	6.0	16.0	Poor P.T. Record
Floor	14B3-100	15.0	38.0	Good P.P.
Floor	3B11-100	14.4	37.0	Good P.P.

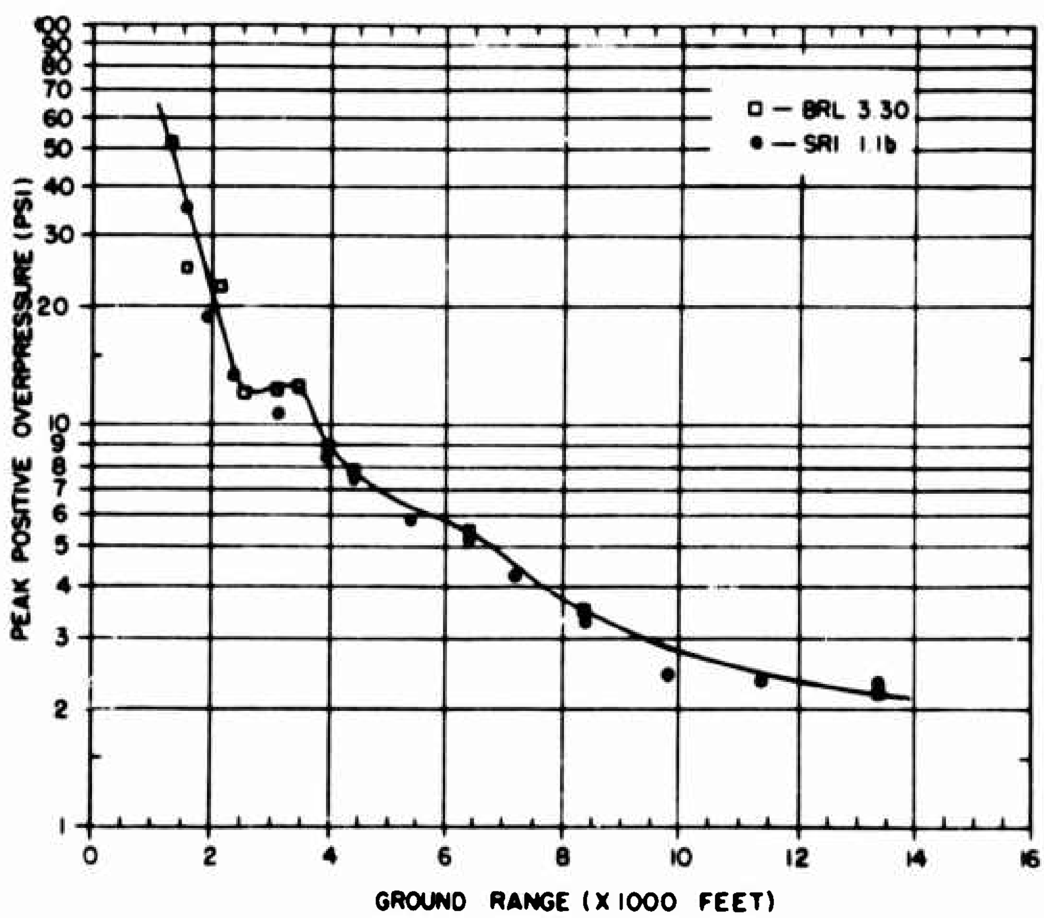


Fig. 3.8 Ground Surface Pressure Vs Distance, Shot 11

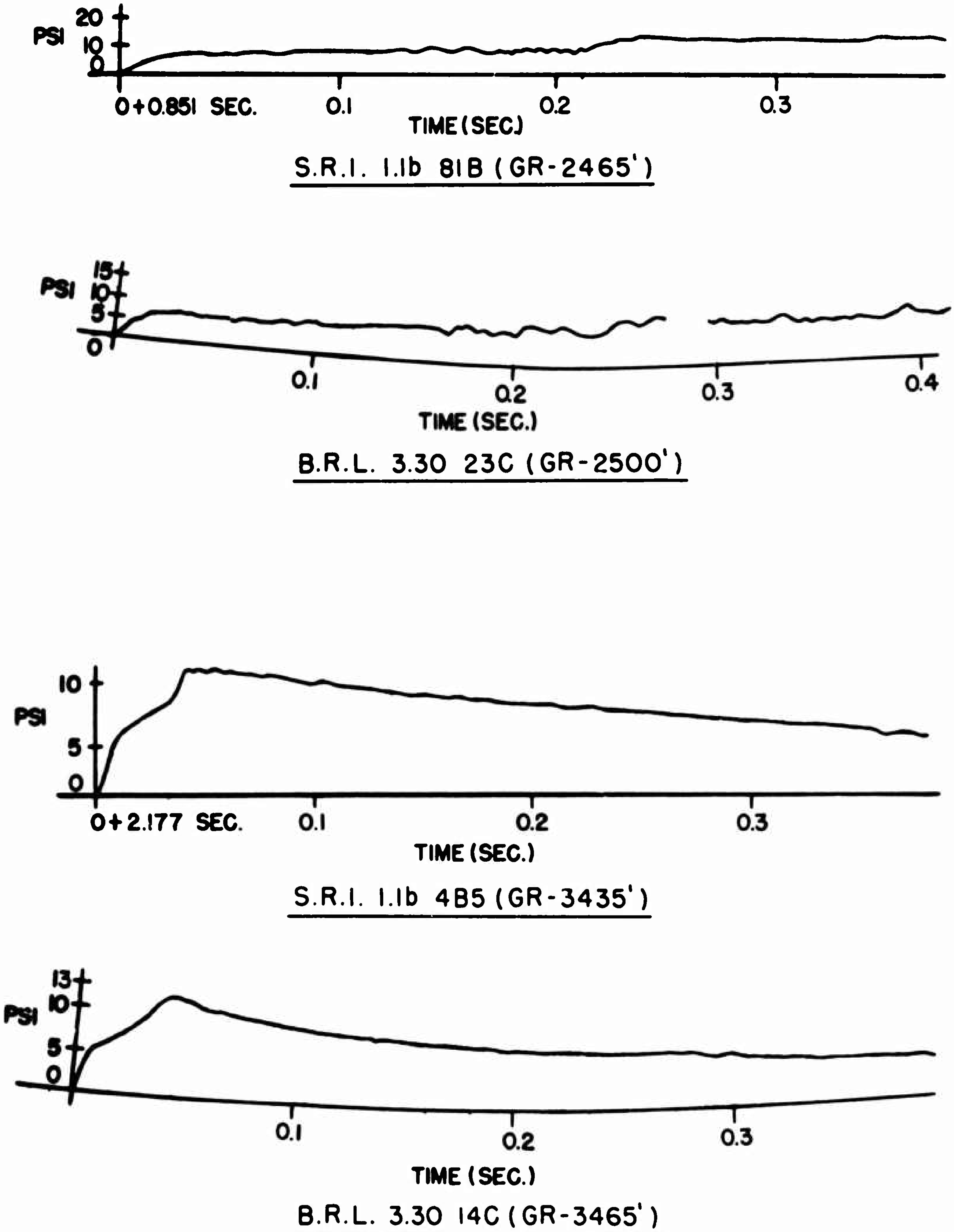
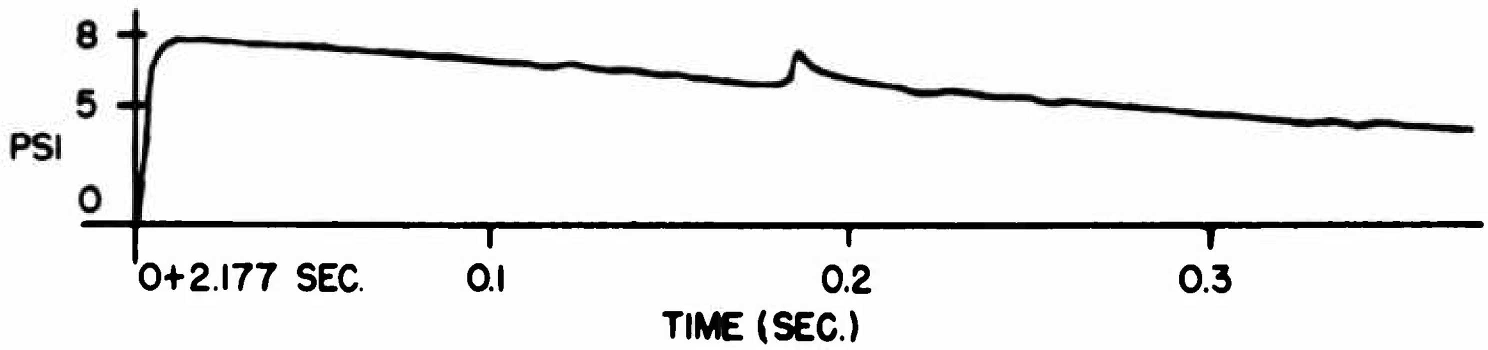
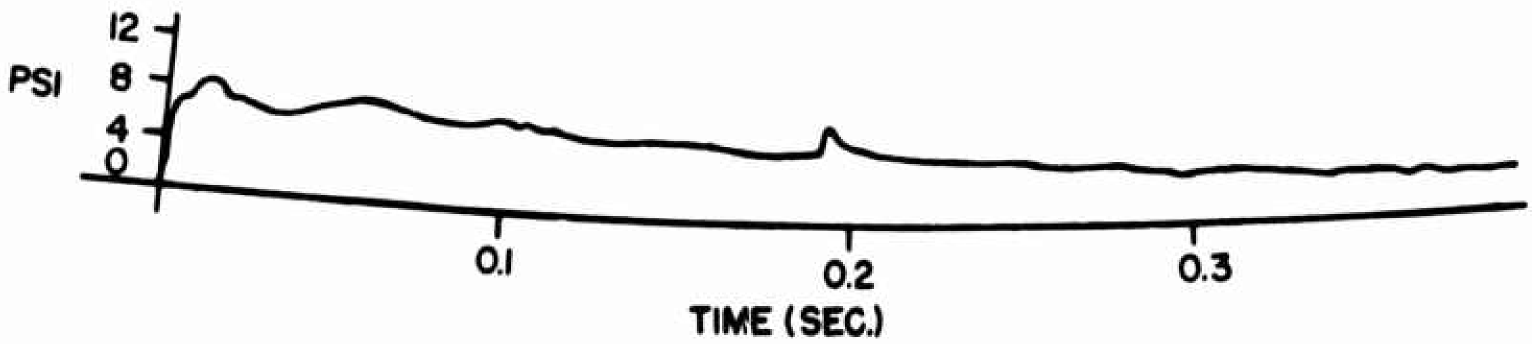


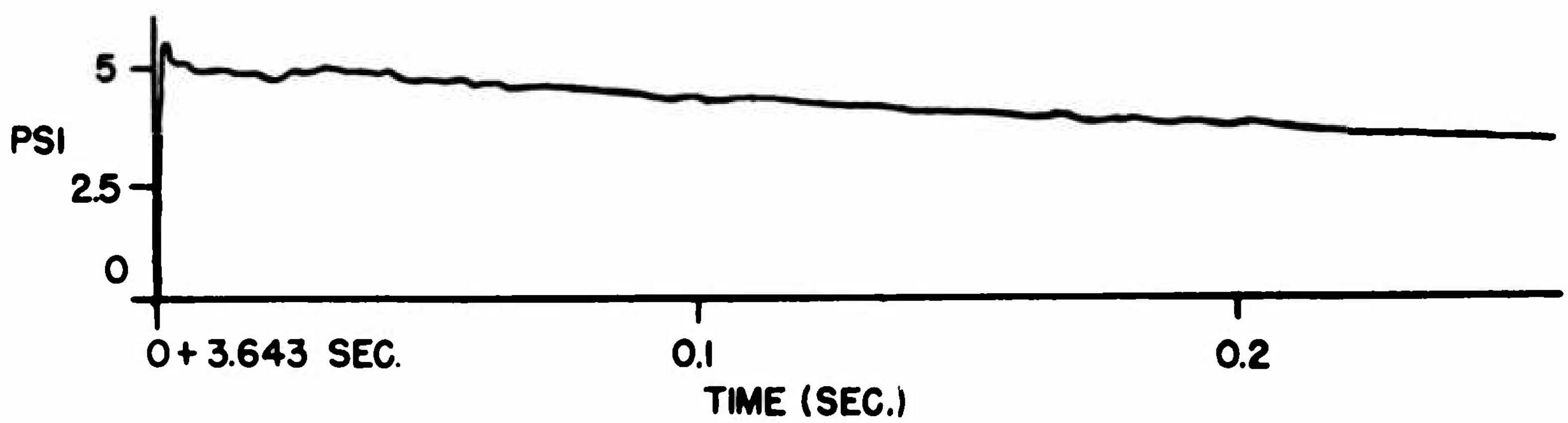
Fig. 3.9 Comparisons of Electronic and Mechanical Pressure-Time Records



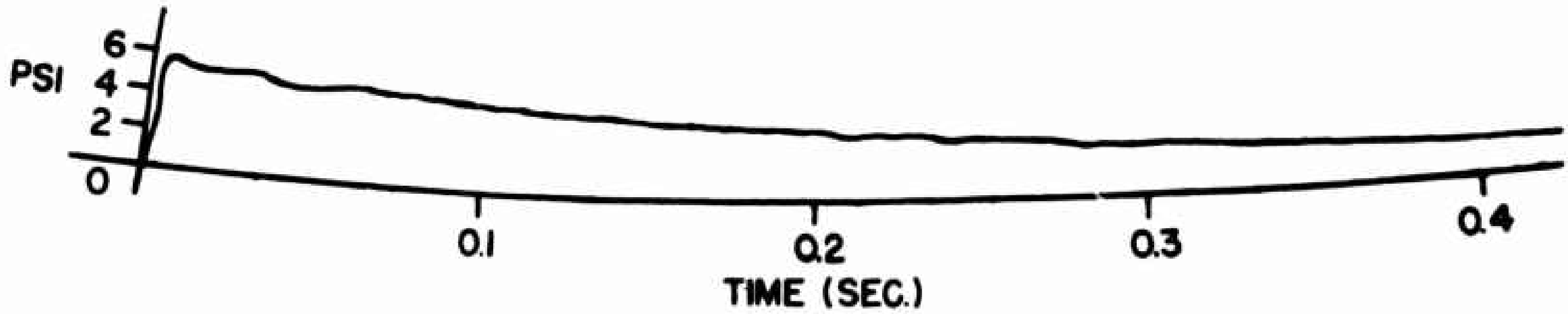
S.R.I. 1.1b 82B (GR-4421')



B.R.L. 3.30 26C (GR-4445')



S.R.I. 1.1b 8B (GR-6404')



B.R.L. 3.30 8C (GR-6425')

Fig. 3.10 Comparisons of Electronic and Mechanical Pressure-Time Records

CHAPTER 4

DISCUSSION, CONCLUSIONS, AND RECOMMENDATIONS

4.1 DISCUSSION

The initiation devices mentioned in this report have many applications in connection with instrumentation problems ever present on field tests of nuclear devices. It is predicted that they will be used with increasing frequency and in increasing numbers on future tests.

4.1.1 Nylon and Carbon Paper Initiators

The use of a simple release mechanism which may be triggered by the thermal radiation of a nuclear detonation has many applications. A piece of nylon thread and a piece of carbon paper are as cheap and as simple a device as one is likely to devise. This series of tests has shown that this simple device is capable of operating reliably in two tenths of a second or less at distances of 1,000 to 10,000 ft from a nuclear detonation of nominal 20 KT size. A thin ribbon of some low melting point plastic, with a half turn to insure a broadside exposure to the radiation should work better and be easier to install than nylon thread.

4.1.2 Nylon and Carbon Paper with a Lens

It has been clearly demonstrated that, for distances greater than 10,000 ft from ground zero, the addition of a comparatively cheap lens to focus the radiation of the nuclear detonation on the nylon and carbon paper will make the device work reliably at distances up to seven and one-half miles from ground zero. On the last shot of this series, Shot 11, two of these devices worked very well at a distance of 19.3 miles. No data have been obtained to substantiate the idea, but it seems reasonable to assume that the addition of a lens would also reduce the lag in initiation of triggering of the nylon and carbon paper at stations close to ground zero.

The addition of a microswitch, which was held in an open contact position by the nylon thread until the thread was melted by the radiation made an initiation device for an electrically driven recording mechanism. The addition of a battery and lead wire, and a fusible link to replace the nylon thread at the mechanical gage, made a remote triggering device which could be placed at any point which could see the radiation of the detonation and still start a gage which was placed inside a dug-out or other location out of sight of the bomb. This is a relatively inexpensive and yet reliable triggering device.

4.1.3 Phototube and Cold Cathode Thyratron with Fuze

A more sensitive triggering device was used, which required a phototube, a cold cathode thyratron, a battery and a fusible link. This simple and inexpensive triggering device could also be used for remote initiation of a gage. The system could probably be still further simplified by using a photocell which generates its own current when excited by radiation and using this current to operate a sensitive mechanically locking relay to initiate and maintain a closed circuit to operate electrical devices. The phototube and cold cathode thyratron device mentioned above worked very well at distances of 5 and 7 1/2 miles for a 30 KT nuclear device. The phototube was shielded from direct sun light and had a neutral density window through which the radiation was received.

4.1.4 Pressure-Time Recording Gages

The heart of the pressure-time recording gages used on this series of shots was the pressure sensing element. These elements have been used for many things for many years. The technique of manufacturing elements which are linear, temperature compensated, have negligible hysteresis, and adequate frequency response to record the pressure-time phenomena of large charges of explosives, has been thoroughly developed. These elements can be manufactured in a wide variety of ranges and at reasonable costs. The pressure sensing elements manufactured for these pressure-time gages were special in that they reduced the volume of air inside the element to a minimum in order to reduce the fill-in time of the element. Every effort was made to reduce the mass of metal which had to be moved and the distance through which it had to be moved to a minimum in order to increase the natural frequency of the diaphragm and, hence, reduce the response time of the element when subjected to a step increase in pressure.

The stylus and its mounting spring were also kept as light as possible consistent with the required rigidity. The mounting spring on the stylus was a critical part of the assembly. It had to be rigid enough to hold the needle vertical when any movement takes place and thus transmit the motion to a scratch beneath the needle point proportional to the movement of the diaphragm; it had to be rigid enough to withstand the torque of the needle point and lever arm as the needle dragged along the moving turn-table surface; and it had to be elastic enough to hold the needle against the recording blank when the ground shock arrived at the gage and still not be so strong as to make an appreciable drag on the recording disc where the needle point was in contact.

One feature which these gages did not have which would be desirable in loading and unloading the record blank and in transporting the gages was a means of lifting the needle clear of the surface of the record blank.

The recording system used in these gages could be applied to many other types of measurements. It was simple, accurate, reliable, cheap to manufacture, and easy to maintain. Unfortunately, the turntable speed of rotation of these gages was too slow. This was particularly true of the nylon initiated gages. The pressure-time curves obtained with this gage were so compressed in time as to render the value of the curve somewhat doubtful. The clock initiated gages recorded at a speed of approximately 0.8 in/sec at the needle point. This was just barely adequate to give millisecond time resolution on the records. A minimum speed of recording at the needle point should be one inch per second. Speeds as high as 14 in/sec have been obtained with this recording system and time resolutions of the order of 20 microseconds were obtained.

It would be desirable for this needle not to retrace any portion of the record. This could be accomplished by a spiral recording on a drum or cylinder. It would also be desirable to record a zero reference line on the record at the time that the signal is recorded. An actual record of time would be desirable on the record and this should be placed on the record at the same time that the pressure is recorded.

The coating of machinists' blue lay-out fluid used on the glass recording discs was satisfactory, but better substances could probably be found. At least easier and better methods of obtaining smooth, even coatings should be investigated. The oil coat on top of the blue coat reduced needle drag and eliminated most of the needle chatter.

The microgroove phonograph needles gave good clean scratches but the regular phonograph needles seem just as good and are considerably cheaper. Sharper needles and finer lines can be obtained by other methods, but it is doubtful that they would increase the accuracy obtainable by an appreciable amount.

The method of mounting the glass recording blank on the turntable can be improved. An accurate hole in the center of the recording disc would simplify reading the records and the obtaining of time data from the record.

The gage cases were strong enough to withstand pressures higher than the 200 psi for which they were designed. The size of the cases should be reduced, especially if it is desired to mount the gages where the shock wave will impinge. The pipe mounting threads on the gage case were of great help. They permitted mounting the gages on pipe towers or fastening an anchor pipe to the gages for ground mounts.

The gage cases and the gage components should be made dust tight, and corrosion resistent. The porous plug in the gage cases permitted pressure equalization under varying conditions of temperature.

4.1.5 Peak-Pressure Recording Gages

The peak pressure gages were easy to use and almost foolproof. Somewhat more scatter was found in the measurements than was expected considering the accuracy of the pressure sensing elements used. A better recording medium would probably improve the accuracy of this type of gage. The record clamping and mounting system was not satisfactory because the clamping device put a positive deflection on the record. This was a small error but an unnecessary one. The pressure sensing elements used in the peak-pressure recording gages should be over-damped to eliminate any overshoot in the record.

4.2 CONCLUSIONS

The flexibility allowed in taking measurements with self-contained and self-recording gages which were independent of starting signals wired in from some other source made it possible to make measurements that otherwise would not be attempted.

4.2.1 Pressure-Time Recording Gages

The pressure-time recording gages were useful auxiliary measuring devices in the form then available. Their accuracy was of the order of $\pm$ 10 percent or better. An improved version of this type of gage should be capable of achieving the accuracy now obtained with the electronic pressure measuring equipment being used. These gages were cheap to build, simple to use, easy to install, and required little labor. The records were easily reduced, required simple and relatively cheap playback equipment, and the data could be quickly obtained as soon as the gages were recovered. The simplicity of the measuring, recording, and data reduction system makes one have faith in the measurements obtained.

4.2.2 Peak Pressure Recording Gages

The peak-pressure recording gages were useful auxiliary pressure measuring devices. Their accuracy was of the order of $\pm$ 15 percent or better in their present form. An improved version of this gage should be able to improve the accuracy achieved. The extremely low cost of these gages (probably 50 dollars or less) makes it possible to use many of them to get peak pressure data and to back them up with smaller numbers of pressure-time gages to show wave shape, duration, and other phenomena connected with the shock wave.

4.3 RECOMMENDATIONS

Based on the results achieved with the self-contained gages used on this series of tests, it is recommended that a development project be set up to improve the gages for future use. It is the belief of the authors of this report that these gages can be made as accurate and reliable as the basic pressure-time measuring systems now used on tests of atomic weapons. The cost of such improved gages should be under 250 dollars per gage.

The savings in money and manpower and the flexibility allowed by making measurements with self-contained gages make these gages extremely useful. The initiation systems, recording methods, and the pressure sensitive elements in these gages are a basis for making self-contained gages for measuring such things as pressure-time under water, water wave actions, ground accelerations, and differential pressure-time measurements associated with the "q" or flow effects of shock waves in air.

It is further recommended that the development of such self-contained gages be undertaken.

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